Large scale connectivity conservation in mountains: A critical response to climate change

A paper presented to the international workshop on protected area management and biodiversity conservation, East Asia. Taipei, Taiwan, 2-3 September, 2008

Dr Graeme L. Worboys
IUCN World Commission on Protected Areas Vice Chair (Mountains Biome)
3 Rischbieth Crescent, Gilmore, ACT, 2905, Australia
Email: g.worboys@bigpond.com

INTRODUCTION

This paper discusses large scale, connectivity conservation areas which interconnect protected areas. It has a special focus on the large, remaining unprotected natural areas found along the great mountain ranges of Earth. These large connectivity areas involve working with people, involve natural lands and provide opportunities for maintaining the connectedness of ecosystem processes; for conserving species, habitat and ecosystems; and for maintaining opportunities for the movement of animals and plants between protected areas. This paper is focused on connectivity conservation areas which can strategically assist the conservation of species at a time of climate change. This focus is an IUCN World Commission on Protected Areas (WCPA) strategic plan action and also a 2015 target of the Convention on Biological Diversity's Programme of Work on Protected Areas (Dudley et al. 2005). The concept of large scale connectivity conservation is introduced by this paper, the forecast impacts of climate change and biome shift are described and the role of connectivity conservation areas in mitigating climate change threats is discussed. Connectivity conservation areas are also an adaptive response to climate change and some examples of large scale connectivity conservation in mountains are provided and how these areas are managed is introduced. Some of the ecosystem service benefits that flow to people and species as a consequence of an investment in connectivity conservation are also briefly described.

CONNECTIVITY CONSERVATION AREAS

Large connectivity conservation areas are natural lands that are not part of the public, private or community protected area systems. They are neither protected areas nor are they the extremely large, remaining wild areas of Earth such as the Boreal Forests of Canada which need to be conserved in their own right. Large connectivity conservation areas are typically tens of kilometres wide and hundreds (if not thousands) of kilometres long, which interconnect many protected areas. They are areas where people live and derive their livelihood and people are a critical part of how these connectivity areas are conserved.

Connectivity areas provide a depth of natural environments that may assist species to respond and potentially survive climate change biome shifts. Connectivity of natural vegetation is needed by most species to able to move effectively move between protected areas within a landscape (Lindenmayer and Fischer 2006). When parks are islands surrounded by modified lands such as cultivation, there are fewer opportunities to conserve a diversity of species in the long term. Large scale connectivity conservation involves managing an entire landscape mosaic of natural lands to facilitate species movements (Bennett 2003). Scientists recognise that this

connectivity conservation may include four distinct types of connectivity within such a landscape scale mosaic, and these are (Lindenmayer and Fischer 2006, Mackey et al. 2008a):
1) Landscape connectivity, which recognises core protected areas that are interconnected by large, naturally vegetated areas;
2) Habitat connectivity, where the natural interconnected landscape retains opportunities for species to move selectively by using preferred habitats;
3) Ecological connectivity, where the natural landscape permits species to contribute to ecosystem diversity and ecosystem function such as a birds transferring rainforest tree seeds across a landscape with their droppings; and
4) Evolutionary connectivity, where the interaction of species with the broader environment permits adaptive and evolutionary changes.

The retention of connectivity conservation areas thus maintains connectivity for species, plant and animal communities and ecological processes (Bennett 2003) which includes maintaining (Mackey et al. 2008a):
1) Ecological functional populations of highly interactive species in the landscape;
2) The habitat needs of highly dispersive fauna;
3) Natural fire regimes; and
4) Natural hydro-ecological regimes.

A focus on large natural lands as connectivity conservation areas has been reinforced by Andrew Bennett in his “linkages in the landscape” book where he states: “The most attractive option for maintaining connectivity is to manage entire habitat mosaics, but this is likely to be effective only where there is largely natural vegetated cover (…)” Bennett 2003). Large scale connectivity conservation was also formally recognised by the IUCN WCPA (Mountains Biome) through a declaration developed by 40 connectivity conservation management experts at an IUCN WCPA workshop held in Papallacta, Ecuador in 2006. This *IUCN WCPA Mountains Biome Declaration* states (Mountains Forum 2007; Worboys et al. 2009 In Press):

> “The maintenance and restoration of ecosystem integrity requires landscape-scale conservation. This can be achieved through systems of core protected areas that are functionally linked and buffered in ways that maintain ecosystem processes and allow species to survive and move, thus ensuring that populations are viable and that ecosystems and people are able to adapt to land transformation and climate change. We call this proactive, holistic and long-term approach connectivity conservation”.

The declaration is a confirmation of the conservation needs of species and ecosystems as well as the needs of people in these large natural areas. The needs of people are discussed further by this paper (hereunder). How connectivity conservation areas actually function for species will differ depending on the species, the duration of time, the environmental condition of the landscape and the dynamic of climate change (Mackey *et al.* 2008a).

Large scale connectivity conservation is intuitive. It just makes sense to keep natural bushland that has always been interconnected in an unfragmented state, particularly when it has been this way for geological epochs. The value of connectivity is also supported by some experimental data, though the actual research completed has been limited. United States researchers have found in South Carolina that habitat patches connected by corridors actually enhanced plant species richness when this was compared with isolated habitat patches (Damschen *et al.* 2006). They also found that the connectivity corridors did not promote the invasion of exotic species. Connectivity conservation successes in the Yellowstone to Yukon (Y2Y) corridor such as movement and use of wildlife overpasses by species; the protection of grizzly bear movement "chokepoints", and the movement of wolves into central Banff due to the removal of impediments (allowing predator-prey relationships with elk to be reinstated), have been achieved thanks to active connectivity conservation management along the Y2Y corridor (Locke in Worboys *et al*. in prep). These successes focus on both wildlife movement and ecological function aspects of connectivity conservation.

Despite concerns expressed in the literature over specific aspects of wildlife corridors, the more encompassing aspect of connectivity conservation has come a long way in the last 30 years (Bennett et al. 2006) and large scale connectivity conservation areas are seen as a wise, long term investment especially given the current evidence that:

"at least in the short term, the total amount of habitat [in connectivity conservation areas] often may be a more important determinant of the status and persistence of species in modified landscapes than the spatial pattern or configuration of habitats" (Bennett et al. 2006).

Based on the precautionary principle, what is important is that large scale connectivity conservation areas be conserved, since they maintain opportunities for many species to survive and move and for ecosystem processes to continue to function (Bennett et al. 2006). The opposite, habitat destruction and fragmentation leads to extinctions (IUCN 2004). Connectivity conservation areas are also a critical response to climate change and the associated biome shifts that may be anticipated.

THE CLIMATE CHANGE THREAT

Climate change is one of the great threats to plant and animal species and water supplies for many parts of the world in the 21st Century. Climate modelling completed by the Intergovernmental Panel on Climate Change in 2007 identified many changes including increased temperatures for the world, marked seasonal drying for many areas such as southern and northern Africa, southern Australia, central South America and southern Europe for the period to 2099 (IPCC 2007). It also recognised marked increases in precipitation for the high latitudes of the northern hemisphere (IPCC 2007). The severity of these forecast changes depends on how quickly and how well people of Earth reduce greenhouse gas emissions, but changes are forecast, they are happening, and the trend in 2008 identifies the emissions accumulating are at the higher end of the IPCC forecasts.

Climate change affects the nature and location of plants and animals. A commonly accepted model for species responses to climate change is for them to move southward or northward (depending on the hemisphere) or up-mountain or both in response to hotter conditions if opportunities to move are available (Dunlop and Brown 2008). Drier conditions at many sites will mean many species will not survive and may be replaced by more drought tolerant species and the natural flow of streams may change from permanent to ephemeral. Glacial ice and snow fed streams of many tropical mountain areas around the world are showing seasonal flow regime changes due to climate change (IPCC 2007). Hotter and drier conditions also means changed fire regimes and hotter and more frequent fires have been forecast for some countries including Australia (Lucas 2007). This ecological process also affects the distribution of species.

Biome shift is a term used by scientists to describe these shifts of plants, animals and habitats (Welch 2005, Mansergh and Cheal 2007). It is part of the dynamic response of life to climate change. Some areas of habitat, because of their unique characteristics, may remain essentially the same despite such changes and may be referred to as “refugia” (Mackey et al. 2008a). For other natural areas, there a number of alternative scenarios for species, and they will (Mansergh and Cheal 2007; Mackey et al. 2008a):

1) Just deal with the hotter (and potentially drier) conditions because of their inherent ability to deal with a wide range of environmental conditions;
2) Alter their genetically permissible physical responses to the changed conditions (such as the growth form of a plant changes from tree to shrub)
3) Adapt (in an evolutionary sense) to the new conditions;
4) Move to new areas;
5) Survive in refugia areas; or
6) Simply die out as a species at that location.

If species are only found in a particular location, then species extinctions may occur as a result of climate change. Professor Stephen Williams of James Cook University Queensland for example identified that for 65 endemic vertebrate species of the Wet Tropics World Heritage Area of Australia, one species would become extinct for a 1.0 degree Celsius climate change caused temperature increase; 35 would become extinct at 3.5 degrees increase, 47 at 5 degrees Celsius and all 65 would be extinct at 7 degrees (Williams et al. 2003). Williams described these findings as an “impending environmental catastrophe” (Williams et al. 2003).

Biome shifts mean that the biodiversity values for a fixed site such as a protected area will change. The park boundary will remain static while over time a passing parade of biodiversity “moves” across the park area. Apart from refugia areas, it means that some of the original values for which a protected area was reserved may no longer be present and the reserve will need to be managed for different natural values in the future. However, these “new” natural values will be just as important in a changing world (Welch 2005). The rapidity of these changes will catch many protected area managers by surprise and they will need to change from managing for specific biodiversity values to a new paradigm of minimising the effects of change (Dunlop and Brown 2008). Biome shift effects will also need to be considered as part of urgent initiatives by nations to finish their national reserve system.

Connectivity conservation areas and greenhouse gases

In the 21st Century, environmental issues associated with the atmosphere are at the top of the political agenda. The issue over greenhouse gases and use of the atmosphere as a pollution sink dominates the news, and responsible solutions and responses to climate change are actively being sought. Connectivity conservation areas and protected area systems provide a critical response to climate change and are part of the solution. They protect natural ecosystems including the photosynthetic processes which help reduce carbon in the atmosphere. Using the sun’s energy, plant photosynthesis converts carbon dioxide to oxygen, and takes carbon from the atmosphere to store it as plant matter (Attiwill and Wilson 2006). It is a sequestration process which helps reduce greenhouse gases and benefits efforts to reduce global warming. Most contemporary carbon “offset” schemes use tree planting and tree growth to mitigate carbon footprints of individuals and companies. In the new carbon economy of the world, financial recognition for land stewardship that retains native bushland (rather than clearing and releasing new carbon) needs to be considered as being more important than new tree planting. Carbon stored in forest ecosystems (green carbon) is very large and immensely important for assessing real carbon mitigation strategies for nations (Mackey et al. 2008b). Preventing deforestation conserves connectivity and prevents significant new amounts of carbon dioxide from entering the atmosphere (Mackey et al. 2008b) The benefits flowing from this stewardship will also need to be long term to maximise the economic returns to people managing these natural lands.

A STRATEGIC RESPONSE TO CLIMATE CHANGE

IUCN’s World Commission on Protected Areas has focused its attention on helping conserve large natural connectivity areas to maximise the conservation of species within and adjacent to protected areas and particularly along many of the major mountain ranges of Earth. It is a strategic response at a time of unprecedented changes caused by climate change. This facilitation of connectivity conservation forms part of IUCN’s response to the 2015 ecological networks target for the Convention on Biological Diversity’s Programme of Work on Protected Areas (Dudley *et al*. 2004).

Connectivity conservation in mountains

Large connectivity areas are being encouraged by IUCN WCPA in seven of the eight biogeographic realms of Earth, and particularly along many of its great mountain areas (Worboys *et al*. 2009 In prep). The actual initiatives are being championed by both government and Non Government Organisations (NGO’s), with a great deal of the early work being pioneered by organisations including WWF, TNC, Conservation International, Birdlife International and the Wildlife Conservation Society. Some examples of mountain connectivity conservation initiatives include:

1) For the northern Rocky Mountains of the USA and Canada, the Yellowstone to Yukon (Y2Y) connectivity conservation corridor extends 3,200 kilometres north-south and is up to 200 kilometres wide (Tabor and Locke 2004, Locke in Worboys et al. 2009 In prep);

2) The rugged and mountainous Albertine Rift connectivity area in the Democratic Republic of Congo, Rwanda and Uganda, an area containing the greatest concentration of vertebrate species for Africa (Plumptre 2004);

3) The Catalonia area of north-east Spain and connectivity to the European Alps (Rafa 2004);

4) The Australian great eastern ranges conservation area from the Australian Alps to Atherton (A2A) (Pulsford and Worboys 2004; Soulé et al. 2006, Mackey et al. 2008c);

5) The Condor Biosphere reserve connectivity conservation in the high volcanoes of the Ecuadorian Andes (Benitez and Cuesta 2004);

6) The integrated network of connectivity conservation corridors in Bhutan (Namgyal 2004; Sherpa et al. 2004);

7) The proposed connectivity conservation area for the central mountain core of Taiwan (Kuo 2002).

These and many other large scale connectivity conservation areas are being established to conserve species, to help protect ecosystems and to provide a response to the threat of climate change.

MANAGING CONNECTIVITY CONSERVATION AREAS

The management of connectivity conservation areas is complex, dynamic and situational, and a conceptual model for such management these has been developed (Worboys et al. 2009 (In prep) (Figure One). The model identifies that management is guided by a shared vision for a connectivity conservation area and a strategic plan is developed to provide broad management direction. The plan is developed based on an understanding of three key settings including the 1) people (social) setting; 2) management (institutional, policy and legal) setting; and 3) nature setting (Figure one). The model recognises internal dynamics for each setting and interactive dynamics between all (Figure one). It clearly identifies the dynamic nature of managing for connectivity conservation and the importance of a strong, binding vision.

The strategic plan describes the purpose of the connectivity conservation area; its vision; its establishment; major threatening processes; and key actions. Typically a large connectivity conservation area will involve more than one nation; multiple organisations; community groups and individuals, and such a plan would provide governance guidance and provide clear accountabilities for actions to be completed and would guide effectiveness evaluation processes (Figure One).

Increased threats to natural areas are forecast (Worboys et al. 2009 In prep) and strategic planning will need to deal with these threats. Both protected areas and their interlinking connectivity areas will be subject to “disturbance events” such as frequent severe fires, severe storms, and severe dryness and this may provide greater opportunities for impacts from introduced species (Worboys 2007, Dunlop and Brown 2008). Connectivity conservation areas (and protected areas) will need to be actively managed to deal with such threats.

One management approach is for communities, landowners, organisations and individuals responsible for connectivity lands and protected area managers to respond in an integrated manner and at a landscape scale to deal with threats such as weeds and pest animals (Worboys 2007). Human impacts will need to be managed including the non-sustainable use of plants and animals; habitat destruction; introduced plants and animals and frequent arson fires. Rehabilitation of previously disturbed areas will be important. Leaders for connectivity conservation areas also need to inspire more research so that science information can guide management actions. This includes modelling, forecasting and adaptive management based on such research information. For large scale corridors, there is scope for a co-operative research programs that measure baseline condition of natural environments; help understand the genetics and viability of key populations of species; assess the nature of threats; measure changes in condition; develop forecasting models, and provide adaptive management research information for users. Social science research can provide critical information needed to effectively manage connectivity conservation areas.

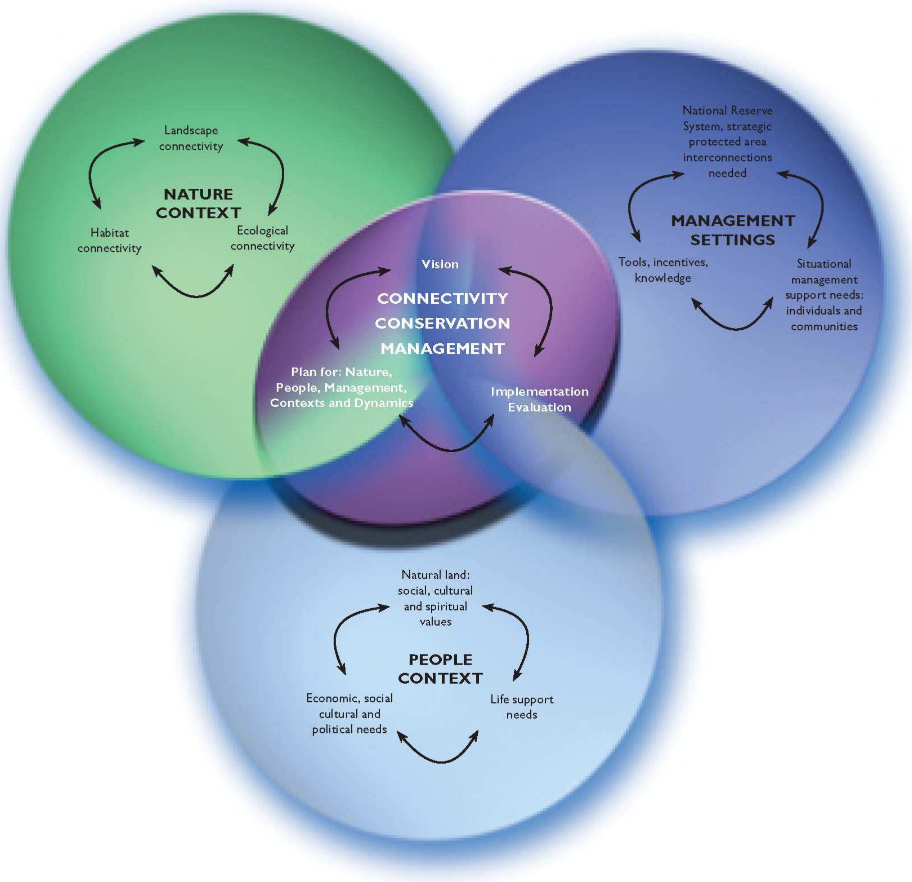

Figure One: Conceptual model for connectivity conservation management (Worboys et al. 2009).

SUPPORT FOR CONNECTIVITY CONSERVATION

Many people around the world have expressed extraordinary support and enthusiasm for connectivity conservation areas. The concept has empowered traditional owners, communities, landowners and individuals who want to respond to climate change and to help protect natural lands, water catchments and species, but have not otherwise been able to do so. Suddenly bold (potentially) national connectivity conservation area approaches have become available to provide strategic context for these smaller individual (and collective) climate change responses. People understand that their efforts are meaningful. Connectivity conservation has the potential to be a major community contribution to national responses to climate change. It has the potential to be a major political force.

BENEFITS OF CONNECTIVITY CONSERVATION

Connectivity conservation areas help to maintain ecosystem functions and help conserve ecosystems, habitats and species. This brings with it additional benefits for both people and for other species. “Healthy” environments provide a range of

ecosystem services which may include (Millennium Ecosystem Assessment report 2005):
1) Provisioning services such as clean air, some foods and clean water;
2) Regulating services such as flood and disease control;
3) Cultural services such as spiritual, recreational and cultural benefits; and,
4) Supporting services such as nutrient cycling that maintain the conditions for life on Earth.
Services such as clean air, clean water and the retention of green carbon also have the potential to provide financial benefits to landowners.

Clean water

Clean drinking water is critical for humans and many other species. If we use the 2800 kilometre long Australian great eastern ranges (A2A) connectivity conservation area as a small case study, we can illustrate the importance of conserving such large scale areas. A2A includes the catchments of easterly (coastal) flowing streams and rivers from the better watered Great Dividing Range and Great Escarpment areas. These streams provide drinking water for the capital cities of Melbourne, Canberra, Sydney, and Brisbane and also service Australian east coast towns, the majority of Australians and multiple east coast tourism towns such as the Gold Coast and Cairns. With a climate change caused drier southern Australia, every drop of water that flows from these catchments becomes more precious. The conservation of the catchment values of A2A easterly (and southerly) flowing streams is directly linked to the economy and prosperity of the most populated part of Australia. Landowners, by retaining natural bushland as part of connectivity conservation are helping to maintain healthy catchments and streams. Great eastern forest streams that are full of life, and clean, clear, and sparkling contrast directly to the brown and sometimes polluted waterways of Australian east coast urban areas. An A2A connectivity conservation area will help to retain these areas in a natural condition and help retain potential future financial returns from water yield for landowners.

Clean air

Like water, the health of the air we breathe is critical. Too little attention however is paid to the role of life on Earth in maintaining a healthy atmosphere. It is usually just taken for granted, but human society needs to be constantly reminded that the atmosphere is both finite and fragile, and with 9.2 billion peoples forecast for 2050, humans have huge potential to influence its condition. If there has been a focus on the health of the air we breathe in the past it has been on limiting the impacts to atmospheric pollution, whether it be greenhouse gases, CFC's (which impacted the ozone layer) or vehicle exhaust pollutants which cause the brown layer of photochemical smog in our cities. The concern by many countries over the potential impact of air pollution to elite athletes at the 2008 Beijing Olympics highlights this point. Regrettably too little attention has been paid to protecting the life processes that help maintain the quality of our air.

Life on Earth generated the air we breathe and the atmosphere that protects us from the life destroying ultra-violet (uv) radiation of the sun. Some 2500 million years ago early life could only survive under nine metres of ocean given an oxygen deficient atmosphere and the extreme effects of the sun's uv-radiation (Ochoa *et al*. 2005). About 2000 million years ago, life had generated sufficient oxygen for it to start to accumulate in the atmosphere and by 490 million years there was sufficient oxygen and an ozone layer in the upper atmosphere to permit the first land plants to survive. Later (about 350 million years ago) the first animals emerged from the oceans (Ochoa *et al*. 2005) and the planet's terrestrial biodiversity evolved from these early plants and animals. Today, the atmosphere is composed of about 21% oxygen, with an (impacted) protective ozone layer maintaining conditions suitable for life. With the prominence of climate change, the importance of protecting the Earth's finite atmosphere and its natural regenerative processes has become paramount.

The role of healthy, functioning ecosystems which contribute clean air, clean water and sequester carbon has become critically important for the survival of many species and for the health of humans. Connectivity conservation areas help to provide such functioning ecosystems, and are an investment in the future of life on Earth including the health and well being of humans.

CONCLUSION

The conservation of large areas of natural lands that interconnect protected areas is a critical response to climate change. Connectivity conservation areas will assist with the conservation of many species that might otherwise become extinct. With climate change caused biome shifts, connectivity conservation will help to maintain functioning, natural catchments and clean water and will contribute to clean air and reduction of greenhouse gases through sequestration of carbon from the atmosphere. As storage areas for green carbon, they retain large areas of carbon which if otherwise destroyed, would compound the global warming problem.

Connectivity conservation areas need active management to deal with more frequent and extreme fire and other threats such as introduced plant and animal species and this requires a new and integrated and responses across the landscape by land management authorities and property owners. Connectivity conservation envisages a new and strategic land stewardship which has potential for being financed from a carbon economy and from water payments. The large connectivity conservation concept has captured the imagination of many individuals and groups, and people see the direct national and potentially, international benefits of their individual local conservation responses. Connectivity conservation has potential to help facilitate national responses to climate change; it has a capacity to contribute to clean air and clean water to help retain the health of people; and it provides opportunities for the conservation of many species of Earth.

ACKNOWLEDGEMENTS

This paper is based on a research paper prepared by the author and commissioned by the World Bank. Dr James Watson of the University of Queensland provided constructive comments on the draft.

NOTE

This paper uses a number of terms quite carefully to avoid any confusion of intent and meaning. The description "large scale connectivity conservation areas" is used, but such areas may also be described in the literature as "linkages in the landscape"; "landscape connectivity"; "biolinks"; "biodiversity corridors"; "corridors"; and, "landscape scale ecological networks" amoungst other terms (Soulé 1999; Bennett 2003; Bennett 2004; Crooks and Sanjayan 2006; Hilty et al. 2006; Lindenmayer and Fischer 2006). The words "large scale" are used to emphasise that the paper is not discussing small wildlife corridors at a scale of (say) hundreds of metres. Rather, it is focusing on some of the World's large remaining natural areas that interconnect two or more protected areas. "Connectivity conservation" is used in preference to corridors to emphasise that the paper deals with habitat connectivity and species movements as well as ecological connectivity which includes the connectedness of ecological processes and ecosystem protection. The word "natural" is used to emphasise that there is a strategic focus in helping to conserving the remaining large, predominantly natural areas that will not otherwise be added to the reserve system (for whatever reason). It is also recognises that small parts of these areas may have been disturbed and may need restoration as part of their management. In using the term "connectivity conservation areas" it is also recognised that the areas include people who may own these lands and who may be both living in and using them.

REFERENCES

Attiwill, P. and Wilson, B. (2006). *Ecology. An Australian perspective* (Second Edition). Oxford University Press. Melbourne.

Benitez, S. and Cuesta, F. (2004). The Condor Bioreserve in Ecuador: use of the functional landscape approach to conservation of montane ecosystems. In (Eds) Harmon, D. and Worboys, G.L. *Managing mountain protected areas: challenges and responses for the 21st Century*. IUCN WCPA. Andromeda Editrice. Colledara.

Bennett, A.F. (2003). *Linkages in the landscape. The role of corridors and connectivity in wildlife conservation.* IUCN. Gland.

Bennett, G. (2004). *Integrating biodiversity conservation and sustainable use. Lessons learned from ecological networks.* IUCN. Gland.

Bennett, A.F., Crooks, K.R. and Sanjayan (2006). The future of connectivity conservation. In (Eds). Crooks, K.R. and Sanjayan, M. *Connectivity conservation*. Cambridge University Press. Cambridge.

Damschen, E.I., Haddad, N.M., Orrock, J.L., Tewksbury, J.J.and Levcey, D.J. (2006). Corridors increase plant species richness at large scales. *Science*. Vol 13. pp 1284-1286

Dudley, N., Mulongoy, K.J., Cohen, S., Stolton, S., Barber, C.V. and Gidda, S.B. (2005). *Towards effective protected area systems. An Action Guide to Implement the Programme of Work on Protected Areas.* Secretariat of the Convention on Biological Diversity, Technical Series No 8. 108 pages. Montreal.

Dunlop, M. and Brown, P.R. (2008). *Implications of climate change for Australia's National Reserve System: a preliminary assessment*. Report to the Department of Climate Change, and the Department of Environment, Water, Heritage and the Arts. CSIRO Sustainable Ecosystems. Canberra.

Harmon, D. and Worboys, G.L. (2004). *Managing mountain protected areas: challenges and responses for the 21st Century.* Andromeda Editrice. Colledara

Hilty, J. (2006). Corridor ecology. *The science and practice of linking landscapes for biodiversity conservation.* Island Press. Washington D.C.

IPCC [Intergovernmental Panel for Climate Change (2007). *Climate Change 2007. The physical science basis.* Cambridge University Press. Cambridge.

IUCN [International Union for the Conservation of Nature] (2004). *2004 IUCN Red List of threatened species. A global species assessment.* IUCN Species Survival Commission. Gland.

Kuo, M. (2002). The establishment and management prospects of conservation corridor for the central mountain core in Taiwan. In (Ed) Huei-Min Tsai. *Proceedings of the Fourth Conference on the Protected Areas of East Asia.* Taiwan Organising Committee for the Fourth Conference on the Protected Areas of East Asia. Taipei.

Lindenmayer, D.B. and Fischer, J. (2006). *Habitat fragmentation and landscape change. An ecological and conservation synthesis.* CSIRO. Melbourne.

Lockwood, M., Worboys, G.L. and Kothari, A. *Managing protected areas: a global guide.* Earthscan. London.

Locke, H. (In prep.). Chapter 3 Yellowstone to Yukon: An outstanding example of connectivity conservation management. In Worboys, G.L., Francis, W. and Lockwood, M. *Connectivity conservation management: a global guide*. IUCN. Rue Mauverney 28, Gland, Switzerland. To be published by Earthscan. London.

Lucas, C. (2007). Climate, bushfires and the Australian Alps. *Powerpoint presentation to the Australian Alps climate change workshop.* Falls Creek, April 16-18 2007. Australian Alps Liaison Committee. Canberra.

Mackey, B.G., Watson, J.E.M. and Hope, G. (2008a). Climate change, biodiversity conservation, and the role of protected areas: an Australian perspective. *Biodiversity*. (In press).

Mackey, B.G., Keith, H., Berry, S.L. and Lindenmayer, D.B. (2008b). *Green Carbon. The role of natural forests in carbon storage.* The Fenner School of Environment and Society, The Australian National University. Canberra.

Mackey, B., Watson, J. and Worboys, G.L. (2008c). *The Alps to Atherton connectivity conservation initiative concept. The scientific basis.* The Australian National University. Department of Conservation and Climate Change. Queanbeyan (In Press).

Mansergh, I. and Cheal, D. (2007). Protected area planning for eastern Australian temperate forests and woodland ecosystems under climate change-a landscape approach. In (editors) Taylor, M. and Figgis, P. Protected Areas: *Buffering nature against climate change. Proceedings of a WWF and IUCN World Commission on Protected Areas symposium, 18th-19th June 2007.* IUCN WCPA. WWF Australia. Sydney.

Mountain Forum (2007). *The Papallacta Declaration. IUCN/WCPA Mountain Biome Workshop-Ecuador 2006.* Mountain Forum Bulletin, January 2007. Available at: http://www.mtnforum.org

Namgyal, T.S. (2004). Sustaining the costs of mountain conservation: lessons from Bhutan. In (Eds) Harmon, D. and Worboys, G.L. *Managing mountain protected areas: challenges and responses for the 21st Century.* IUCN WCPA. Andromeda Editrice. Colledara.

Ochoa, G., Hoffman, J. and Tin, T. (2005). *Climate. The force that shapes our world – and the future of life on Earth.* Rodale. London.

Plumptre, A. (2004). Priority sites for conservation in the Albertine Rift and the importance of transboundary collaboration to preserve landscapes. In (Eds) Harmon, D. and Worboys, G.L. *Managing mountain protected areas: challenges and responses for the 21st Century.* IUCN WCPA. Andromeda Editrice. Colledara.

Pulsford, I. and Worboys, G.L. (2004) The Australian Alps and the Great Escarpment of Eastern Australia conservation corridors In (Eds) Harmon, D. and Worboys, G.L. *Managing mountain protected areas: challenges and responses for the 21st Century.* IUCN WCPA. Andromeda Editrice. Colledara.

Rafa, M. (2004). Managing mountain areas in Catalonia (north eastern Spain) beyond protected areas: the role of the private sector and NGO's. In (Eds) Harmon, D. and Worboys, G.L. *Managing mountain protected areas: challenges and responses for the 21st Century.* IUCN WCPA. Andromeda Editrice. Colledara.

Sherpa, M.N., Wangchuck, S., and Wikramanayake, E. (2004). Creating biological corridors for conservation and development: a case study from Bhutan. In (Eds) Harmon, D.

and Worboys, G.L. *Managing mountain protected areas: challenges and responses for the 21st Century*. IUCN WCPA. Andromeda Editrice. Colledara.

Soulé, M.E., Terborgh, J. (Eds). (1999). *Continental conservation. Scientific foundations of regional reserve networks.* Island Press. Washington D.C.

Soulé, M.E., Mackey, B.G., Recher, H.F., Williams, J.E., Woinarski, J.C.Z., Driscoll, D., Dennison, W.C. and Jones, M.E. (2006). The role of connectivity in Australian conservation. In. (Eds). Crooks, K.R. and Sanjayan, M. *Connectivity conservation*. Cambridge University Press. Cambridge.

Tabor, G., and Locke, H. (2004). Yellowstone to Yukon Conservation Initiative In (Eds) Harmon, D. and Worboys, G.L. *Managing mountain protected areas: challenges and responses for the 21st Century*. IUCN WCPA. Andromeda Editrice. Colledara.

Udvardy, M.D.F. (1975). *A classification of the Biogeographical Provinces of the World.* IUCN Occasional Paper No 18. International Union for the Conservation of Nature. Gland.

UNEP [United Nations Environment Program] (2007*). GEO 4. Global Environment Outlook. Environment for Development.* United Nations Environment Program. Kenya.

Welch, D. (2005). What should protected area managers do in the face of climate change? The *George Wright Forum.* Vol. 22. No 1. pp 75-93.

Williams, S.E., Bolitho, E.E. and Fox, S. (2003). Climate change in Australian tropical rainforest: an impending environmental catastrophe. *Proc Roy Soc Biol Sci* Vol 270, No 1527, pp. 1971-1978.

Worboys, G.L. (2007). Managing Australia's protected areas for a climate shifted spectrum of threats. In (editors) Taylor, M. and Figgis, P. Protected Areas: *Buffering nature against climate change. Proceedings of a WWF and IUCN World Commission on Protected Areas symposium, 18th-19th June 2007.* IUCN WCPA. WWF Australia. Sydney.

Worboys, G.L., Francis, W. and Lockwood, M. (In prep). *Connectivity conservation management: a global guide*. IUCN. Rue Mauverney 28, Gland, Switzerland. (To be published by Earthscan, London, 2009).