

*Research*

## **Australian Pastoralists in Time and Space: The Evolution of a Complex Adaptive System**

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**ABSTRACT.** Newcomers and exotic livestock have displaced indigenous hunter-gatherers from Australia's drylands over the past 200 yr. This paper seeks to learn from and explain the adaptive process involving the initially naïve newcomers, their stock, and Australia's ancient landscapes. We review pastoral adaptation at the national, regional, and enterprise scales. These scales are linked, and so we use "panarchy" theory with its concept of "adaptive cycles" as an analytical framework. Past pastoral adaptation can be summarized by changes in key linkages: pastoralists (1) are now connected to more individuals than when they first moved into the rangelands, but are less reliant on local hubs for these connections; (2) have weaker links to the environment as environmental feedbacks have been reduced; (3) have stronger links to alternate land uses, but weaker links to governance; and (4) have stronger links to the global economy. Further change is inevitable. Pastoralism is likely to remain as the core activity in Australian rangelands, but the dynamic linkages that shape the system will, in future, connect pastoralists more strongly to post-production economies, information and more distant social networks, and to a more diverse group of land users.

**Key Words:** *complex systems science; Dalrymple Shire; grazing systems; rangelands; semi-arid.*

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### **INTRODUCTION**

In rangelands dominated by grazing enterprises, domesticated livestock graze on native vegetation. Such enterprises use few external inputs, and revenues are strongly constrained by low productivity primary resources, which vary in time and space. The sheer vastness of rangelands hides their complexity. Grazing systems, like all social-ecological systems, are essentially a collection of objects, e.g., people, institutions, physical environmental elements, that are linked by processes, leading to cross-scale interactions, adaptive behavior, nonlinearities, and dynamics involving thresholds of change between alternative "states" (McIvor and Scanlan 1994, Anderies et al. 2002, Hodgkinson and Muller 2005). Rangelands are indeed complex adaptive systems (Gross et al. 2006). There is increasing recognition that in such systems, the most appropriate management regimes, rather than seeking control, seek to build the system's ability to maintain its key processes and structure in the face of perturbations (Gunderson and Folke 2005).

Indigenous hunter-gatherers were already in southeastern Australia 40,000 yr ago (Bowler et al. 2003). They may have had major initial impacts when they arrived (Flannery 1994), and their communal institutions and natural resource management systems adapted to deal with climatic uncertainty and spatiotemporal variation in resources (e.g., Berndt and Berndt 1981). The past 200 yr have seen the displacement of the Australian indigenous system and the establishment of a pastoral system in which privately owned cattle and sheep graze native vegetation. Rangelands cover around 70% of Australia, and presently at least half of these rangelands are grazed (Chudleigh and Simpson 2004).

Resource variation is a feature of rangelands worldwide, and accordingly a range of institutions have evolved to help buffer variability, most involving networks and rules allowing for livestock mobility (e.g., Perevolotsky 1987, Scoones 1992, Rouchier et al. 2001). The purpose of this paper is to analyze the evolution of the pastoral system in Australia as it adapted to this uncertainty in resource availability in space and time. We focus on national

and enterprise scales. The enterprise-scale data are from the Dalrymple Shire, which adds a new Australian rangeland case study to existing analysis (Walker and Abel 2002). Our aim is to add to the understanding of adaptation in the Australian rangelands so that we can help inform the path to the future.

We use resilience theory's adaptive cycles, described below, as our framework, though we do not seek to test the concept. The adaptive cycle is useful here, because it allows us to summarize the process by which our new system developed its identity, i.e., its key objects, the links between these, and the resulting functions (Cumming et al. 2005). Having provided an identity, the adaptive cycle provides a framework for exploring how, when, and why identities can change.

### **THEORY: ADAPTATION AT MULTIPLE SCALES**

Most attempts to explain changes in time and space in rangeland systems select a time, spatial, or social scale for the analysis, and identify drivers, parameters, and variables at that scale. Authors have thus analysed how government policies affect land use (e.g., Hannam 2000), how stocking rate affects vegetation (e.g., Northup et al. 2005), biodiversity (e.g., Martin et al. 2005), and landscape systems (e.g., Ludwig and Tongway 2000), and how waterpoints (e.g., Landsberg et al. 2003) and invasive species (Grice 2006) affect biodiversity.

The time, spatial, or social scale selected for each of these analyses determines the drivers (Harrington et al. 1984); and therefore, the conclusions drawn about the causes of change. There are two reasons. First, drivers change over time, so the time scale chosen determines which drivers are identified. Second, rangelands are open systems, and the "boundaries" we draw around subsystems are crossed by multiple influences from other subsystems. Boundaries are an artifact of the human need to simplify in order to understand, but the danger in using them is that some understanding is inevitably lost through the neglect of interactions across boundaries. The challenge is to improve our understanding of the causes and consequences of change at more than one social, spatial, and time scale without hiding those understandings in overcomplexity. As a general rule, to develop an understanding that is no more complex than

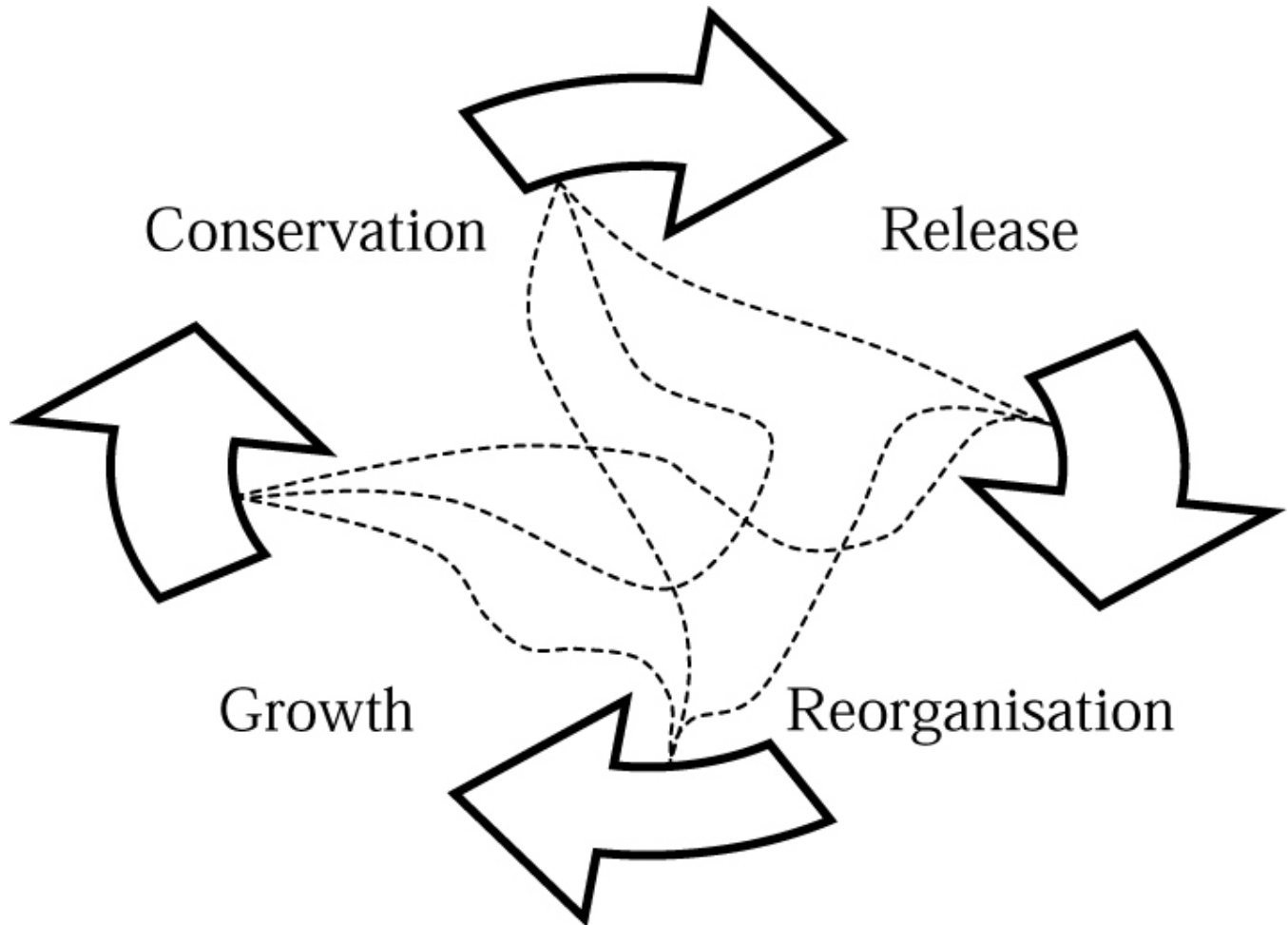
necessary, some argue that no more than five variables are needed to understand social-ecological dynamics at a particular scale (see Walker et al. 2006).

Holling and Gunderson (2002) deal with changes in system drivers over time through their adaptive cycle concept. The term "cycle" could imply a periodic return of the system to its initial conditions, the antithesis of evolution. This is not the intention. Social-ecological systems do "evolve," but adaptive cycle theory proposes that their behavior during this evolution can be characterized by four stages. Holling and Gunderson argue that a system at a particular scale tends to iterate through a cycle of growth, conservation, release, and reorganization (Fig. 1; Holling 1987). Each stage is characterized by different drivers (Abel et al. 2006). The conservation stage is characterized by the concentration of resources in a few dominant species, monopolization of political-economic power by a few interest groups, uniformity of ideas and culture, low rates of innovation, and low capacity to adapt to new problems and opportunities. These characteristics cause the system to lose resilience and be prone to enter the release stage. Although a release event is more likely during the late conservation stage, it could, depending on the strength of the external disturbance, be triggered during growth or reorganization (Walker et al. 2006).

Release is so called because resources and "mental models" (Abel et al. 1998) are freed, new or latent ideas can be expressed, and a diversity of species is potentially able to use resources released by erstwhile dominants. The release creates new opportunities, which are taken during the reorganization stage that may follow. During and following reorganization, the system can return to its former configuration. In our case, it may remain a pastoral system, or switch to a new one, e.g., a tourism-and-wildlife system (Abel et al. 2006). Once reorganized in a new or a previous configuration, growth takes the system toward a new conservation stage.

Holling and Gunderson address the challenge of cross-scale linkages through the concept of "panarchy," which is a set of linked adaptive cycles that operate at several scales. The broader-scale cycles tend to proceed more slowly than the finer-scale ones. They also tend to dominate and drive the finer scale, faster cycles. However, according to

**Fig. 1.** The “Adaptive Cycle” holds that systems move through a sequence of states (large arrows), though the exact sequence may vary (indicated by thin lines).



panarchy theory, there are occasions when a broad-scale and slow cycle may be driven by a fine scale and fast cycle. This is predicted to be especially likely when a broad-scale system of low resilience undergoes reorganization, opening new opportunities and sensitivities to the influences of internal processes.

In keeping with panarchy theory, we view rangelands as a collection of adaptive cycles. Although the finer-scale cycles tend usually to be driven by the broader-scale ones, we do not expect them to be synchronized across nor within scales, because of strong stochasticity, different local

histories (McAllister et al. 2006b), and ecological attributes.

### Three scales of adaptation

We focus on adaptive cycles at three scales: national, regional, and property, a commercial animal production unit that may have some nonagricultural income sources, e.g., kangaroo shooting and goat harvesting (Fig. 2). By national/state adaptive scales, we refer to Australia as a whole, though we are most interested in pastoral governance.

A region is any tract of country with more or less definable boundaries. It may be large or small in area. By common usage regions have come to mean tracts of several hundred km<sup>2</sup> or more. Regions are commonly defined for political, administrative, service delivery, and data-collection purposes. Their boundaries are rarely ideal for research. However, as government data are collected and classified in accordance with these boundaries, researchers often conform to them. Whereas we necessarily refer to formally defined administrative regions, our concept of a region is a group of enterprises linked through social networks. Referring back to panarchy theory, we see these networks as connected across the formal boundaries of the region to nodes in other pastoral regions, and nodes in the state and national system.

The remainder of this paper is an attempt to examine the evolution or adaptation of Australian pastoral systems with our framework. To do this, we examine adaptation at each of our focal scales, examining the enterprise scale using a case-study region we know well, loosely corresponding with the boundaries of the Dalrymple Shire, northeast Australia. First, we consider the adaptive cycle of Australia following British occupation.

## **GOVERNMENTS AND THE PASTORAL SYSTEM**

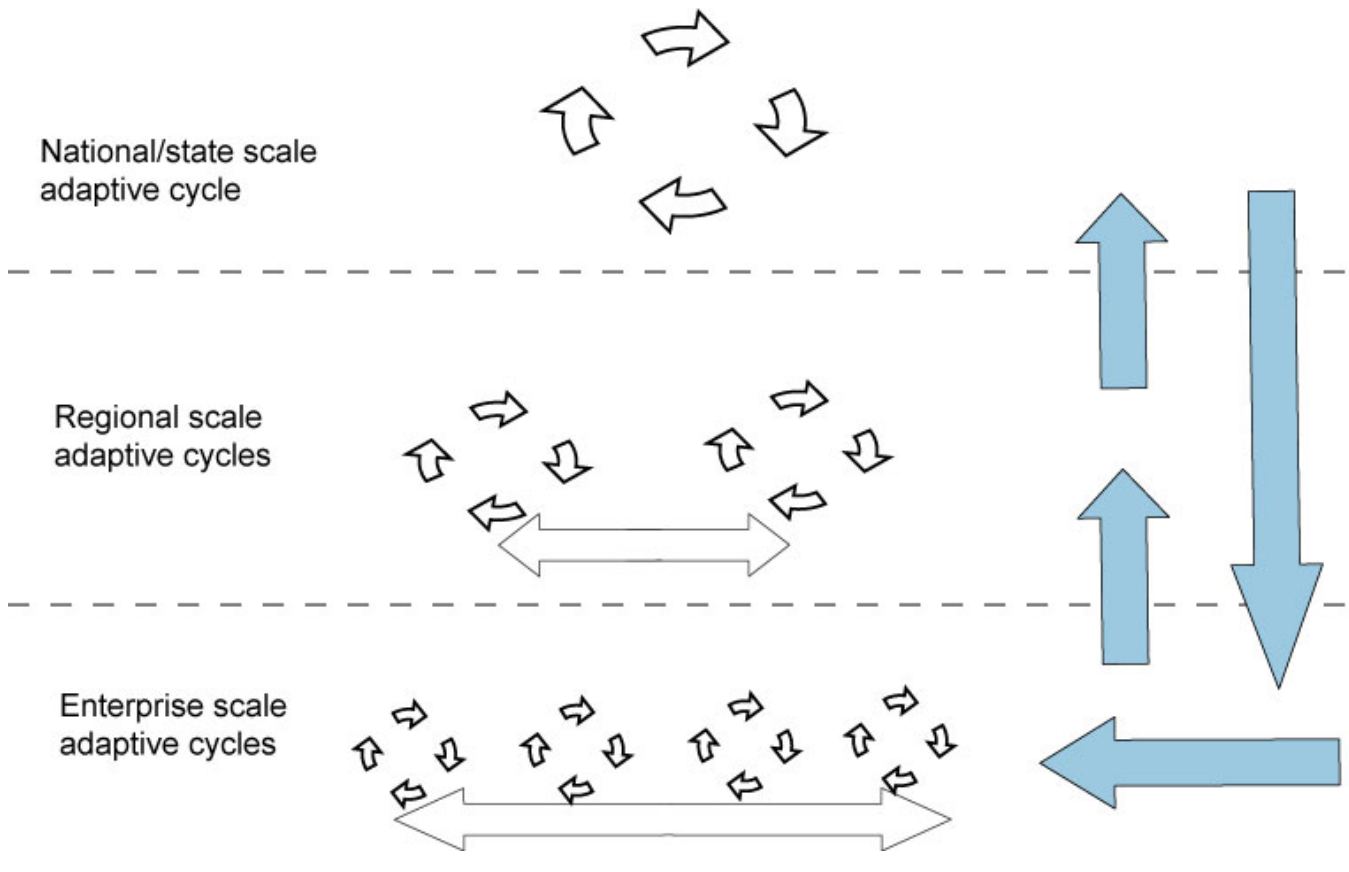
At broad state and national scales, pastoralists have not been external agents in total control of Australia's rangeland, but neither have they been passive victims of circumstance. Instead, pastoralists have been an integral component of rangeland systems, at times strongly influencing the pathway of development and at others being constrained by their biophysical and social environment (Table 1, Fig. 3). The benefits and costs of cross-scale interactions differ across the scales (Adger et al. 2005), and in Australian rangelands the balance of such differences varied in time and space as relationships between governments and pastoralists changed: Australia developed from a set of lightly populated colonies reliant on agriculture to a federal nation with a diverse economy supporting 20 x 10<sup>6</sup> people today. Following adaptive cycle theory, we divide this development into the stages of the cycle.

## **Growth**

The development of Australian primary industry has been characterized by adaptation to the harsh, unpredictable climate, and infertile, well-weathered soils prone to salinity. A major driver was world demand for wool, and large capital investments enabled rapid development. Early pastoral pioneers quickly perceived permanent surface water as a limiting factor, and consequently moved along river corridors (Durack 1967). They had few restrictions on their movements, so in these early days they practiced transhumance, and occupied land in multiple sites such that they could use climatic gradients to follow forage and markets. These "squatters" occupied huge tracts of land outside the physical range of governments' controls, and owing to the insecurity of their illegal tenures, investment in infrastructure was limited.

When surveyors and the law finally caught up to frontier pastoral regions, leases were established to legitimize occupation of the land by squatters, who had often become rich and politically powerful. This was largely due to the wealth generated by the sheep industry; it overtook gold as Australia's largest export commodity in 1871 (Boehm 1993). Pastoralists developed strong influence over governance and legislation. We interpret this influence as a strong pastoral-government link, which helped pastoralists further promote the expansion and development of the industry. This included continual pressure for the opening of new lands for pastoralism and for provision of infrastructure to service new development in remote areas. Concessions were also gained in setting low prices for the sale and lease of land, prescribing pastoralism as the land use for most leased land, and improving lease conditions and the security of tenure on leased land. Pastoralists, as part of the agricultural sector, also lobbied at various times over the last century and a half, often successfully, for various forms of subsidy including drought relief, infrastructure development, price supports, structural adjustment assistance, and tax incentives (Davidson 1992, Godden 1997). Growth was also enabled by externally generated technologies; key examples are fence-wire and bore drills in the 1860s, freezing of meat toward the end of the century, and earth moving machinery, i.e., bulldozers, after World War II, which were used to cheaply increase the capacity and distribution of water in the form of large pits dug into the earth to store seasonal rains.

**Fig. 2.** Adaptation of Australian pastoral enterprises involves cycles of adaptation at multiple scales, which have both bottom-up and top-down links.



### Conservation

The political-economic influence of the pastoralists was countered increasingly by rapid immigration and growth in the population following the establishment of a mining industry. Many lived in towns and opposed the “squattocracy.” Driven by this countervailing political pressure, governments made increasingly effective attempts from the 1860s to reappropriate land from large leases to be redistributed (Dovers 1994). Governments assumed that closer settlement and social equity would build and sustain regional communities (Williams 1975). Another driver of closer settlement was the perceived need to populate the rangelands, occupied by indigenous peoples, to legitimize the colonists’ claim over the sparsely populated continent (Williams 1975, Day 2001), and to “tame” the outback (Quinn 2001).

The result of closer settlement in many grazing lands (but not all McAllister et al. 2006b) was a fragmented landscape with properties too small to consistently generate sufficient revenue to support families, and limited natural capacity to buffer resource variability (Noble 1997). The conservation stage of Australian pastoralism was therefore characterized by relatively dense settlement of often-unviable properties on which pastoralists intensified grazing by building artificial waterpoints. Grazing and the proscription of burning fostered shrub increase, which reduced the productivity of land (Noble 1997). Economic reliance on livestock over whole regions made the system highly vulnerable to rainfall and market fluctuations. Uniformity in property sizes also reduced resilience as different sizes of property have different production strategies and are affected differently by rainfall and market variations (Young et al. 1984).



**Table 1.** Key dates in government-pastoral interactions.

Date	
1788:	European colonisation of Australia
1840:	End of convict transportation and cheap labour
1852 and after:	Mining drives rapid trebling of colony's population and urbanisation, leading to end of pastoral political hegemony by 1890s.
1871 and after:	Wool overtakes gold as largest export earner.
Late 1890s:	Wool price collapse
1930s:	the "Great Depression"
After 1945:	Soldier settlement on small unviable leases for returning WWII veterans
1950s:	End of closer settlement policies.
1980–1990s:	Environmentalism growing among urban voters leads to policy responses in 1990s.

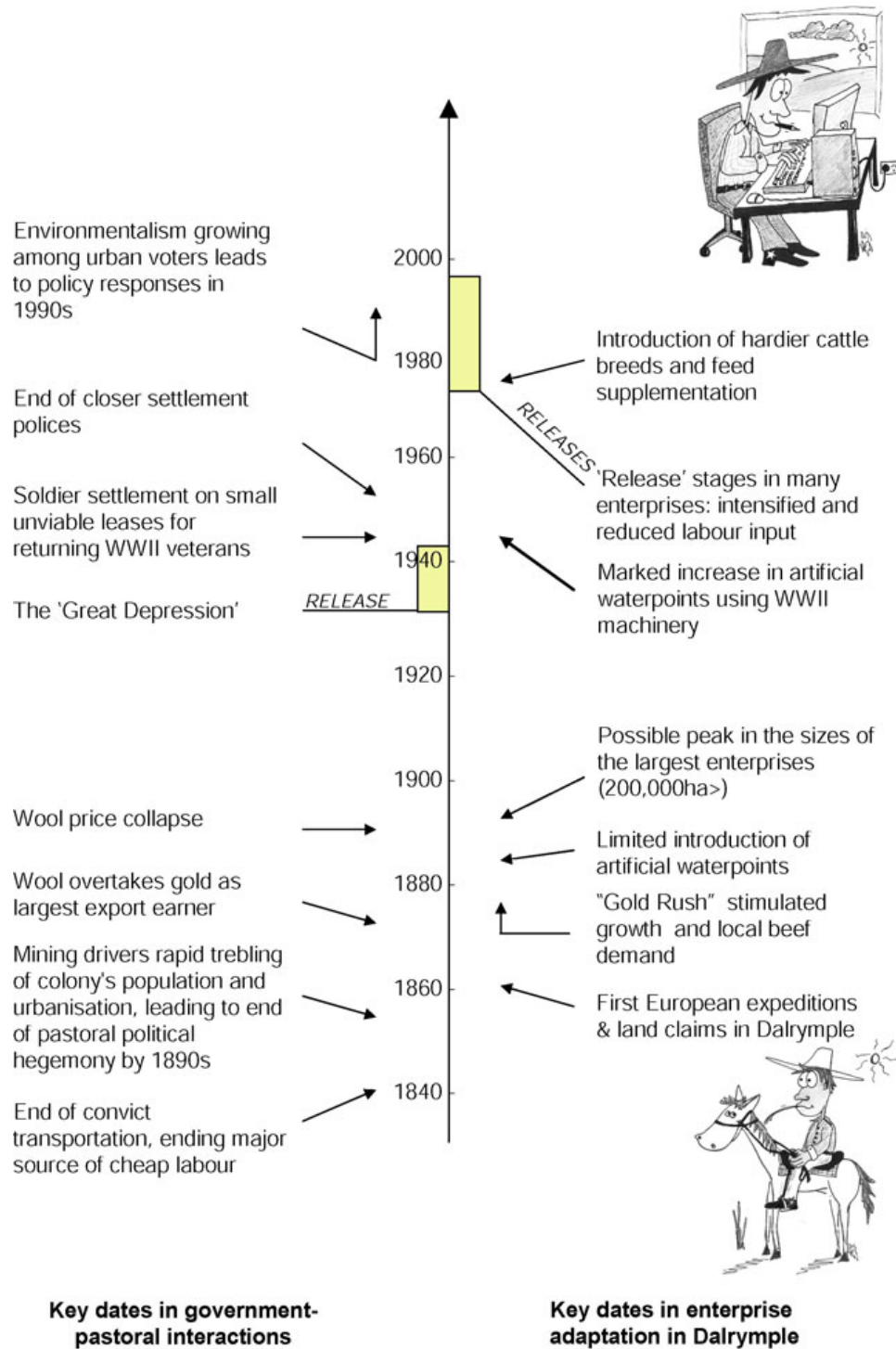
### Release and reorganization

Resilience is the ability of a system to recover and maintain its structure, i.e., its linkages and key functions, or identity following perturbation (Cumming et al. 2005). The Australian pastoral system displayed its resilience by surviving the recession of the late 1890s. A major driver was widespread loss of confidence in share markets, and consequent disinvestments from multiple sectors. Australian banks collapsed, wool prices fell severely, and pastoralists were beset by debt. In western New South Wales the recession coincided with prolonged and severe drought (McKeon et al. 2004), but the drought did not affect our case-study area, the Dalrymple Shire. In western New South Wales, under the combined effects of recession and drought, 50% of leases came into the hands of banks or pastoral companies through individual bankruptcies. The departure of the lessees caused losses of human and social capital. Damage to infrastructure from shifting sand and catastrophic losses of sheep represented losses of physical and natural capital. Major institutional and organizational changes followed this release event, which occurred during a growth stage in the adaptive cycle, not the conservation stage (Abel et al. 2006). It is likely

these adaptive changes prepared the Australian pastoral system better for the Great Depression of the early 1930s, which caused individual bankruptcies in our case-study region as elsewhere, but recovery of the pastoral system followed. The present-day system, described by Ludwig and Stafford Smith 2005 and Gross et al. 2006, is a product of these shocks.

Australian pastoralism has also had to adapt to a changing social environment. The political power of pastoralists during the European settlement of Australian rangelands ensured that economically productive pastoral use of land was emphasized, often at the expense of other societal values. With the decline in the relative economic importance of pastoralism, the political power of pastoralists steadily eroded. In recent decades there has been growing demand to accommodate other values from rangelands (Hunt 2003), including protection of ecosystem services, access to land by indigenous Australians, and maintenance of biodiversity. Pastoralists are now having to adapt to meet these sometimes conflicting demands in the use and management of rangelands (Abel et al. 2002, Gordon and Nelson, *in press*), either on the land they own or through changes brought about during lease

**Fig. 3.** Timeline, showing key events in government-pastoral interactions, and Dalrymple Shire pastoral-scale adaptations (original drawings by Brendan Ebner).



renewal. This will include negotiations with other sectors of society about meeting the costs associated with maintaining and improving these broader benefits.

## **ADAPTATIONS OF PASTORAL ENTERPRISES**

Drivers for property-scale adaptation are both endogenous and exogenous to the Australian pastoral panarchy. Most are exogenous, e.g., international prices, technology, and rainfall, but many are at least partially endogenous, e.g., labor, number, and age of offspring, technology adoption, and “environmental learning” of the type that Measham (2006) discusses. We focus here on enterprise-scale adaptation. Variation between enterprises means that some may collapse and others survive the same perturbation, so the magnitude and extent of the impact upon the regional or state and national systems depends on how widespread is the collapse of individual properties. Further, the drivers of any “release” will affect different regions differently depending on the region’s own unique, but linked, adaptive cycle. For example, even if a drought is experienced widely, rainfall is still likely to be more deficient in some areas than others. Accordingly, releases at the enterprise level are more likely to have a regional impact than impact the national adaptive cycle, as exemplified by the 1895–1900 release event in the New South Wales rangelands discussed earlier. This happened, we propose, because drought and recession coincided.

Our case study is of property-scale adaptation in the cattle-dominated Dalrymple Shire in Queensland’s northeast, for which information is available on both general (Stokes et al., *in press*) and property-specific adaptation; enterprise spatial boundaries and ownership are dynamic, so we refer to several published case studies by the present station names: Hillgrove (Mann 1993); Maryvale (Allingham 1977); and, Trafalgar (Landsberg et al. 1998).

### **Growth**

In 1861, the year Queensland separated from New South Wales, the Dalrymple Shire opened to pastoralism following favorable reports by explorers in 1845 and 1860 (Table 2, Fig. 3). With only natural water available, pioneers were limited

to areas that could be used for grazing. The landscape contained “key resources,” such as lagoons along ephemeral rivers, which provided reliable access to water. Often pioneers sought only to control these key resources, and this was reflected in the pattern of lease ownership (Queensland Treasury 1861, Stokes et al. 2006).

Sheep proved unsuitable in the Shire and were generally replaced with European bred cattle within a decade (Allingham 1977). A major driver of growth was the 1870s gold discoveries, which brought thousands of miners to the region and created a demand for meat. The “rush” ended just as World War I started and the local market was drastically cut, but demand for meat continued to drive growth as a market for tinned export beef developed. World War II later stimulated a similar demand.

As a generation of pioneering-pastoral families established in the region, many of the speculative pioneers left (Allingham 1977), and “newcomers” continued to arrive (Landsberg et al. 1998). For the original pioneers, succession planning seemed to be a major factor in enterprise building and adaptation (Durack 1967, Allingham 1977) as enterprises were expanded to accommodate increasing numbers of offspring. However, around the 1890s, state government concurrently reappropriated some parts of pastoral leases under the closer settlement policy (Queensland Treasury 1861). For example, resumptions reduced the Allingham’s holdings from 200,000 ha to 65,000 ha (Mann 1993). Resumed land was redistributed. Many of the new smaller holdings established were not viable and were once again purchased and incorporated into more extensive production, a clear “release” for the leaseholders involved.

### **Conservation**

When World War II ended ex-military bulldozers and trucks became readily available. The cost of installing dams plummeted, and with the increased distribution of water, enterprises became more uniformly grazed and stock numbers per total area could be increased. This compensated to an extent for the decreases in property size and was probably driven by it (Stokes et al. 2006). Queensland Government policy continued to reappropriate land to resettle soldiers and to promote closer settlements. Reappropriations finished around the



1950s (McAllister et al. 2006b); technology advances were incremental. On Trafalgar, apart from the development of four wells and seven dams, some feed supplements were introduced.

### Selective release and reorganization

After the 1950s the cost of production began to rise faster than prices, reducing pastoral margins. In the late 1960s Federal Government increased labor costs by introducing a minimum wage, and finally, the combination of below-average rainfall, a price slump, and high interest rates, caused some Dalrymple Shire enterprises to collapse, and others to restructure (Goodall 2001, Stokes et al. 2006). Three characteristics of enterprise identity appeared, in hindsight, to determine whether it had sufficient resilience to endure this pressure: access to a large area, infrastructure to reduce labor costs, and a low level of debt.

In reorganizing, wooden fences were replaced with labor-saving steel ones, and additional fences were installed to allow more precise stock management. Feed supplements were introduced and most importantly European cattle breeds were replaced with hardier Indian breeds. The combination of water and breed spread grazing pressure more widely across the landscape and intensified it (Fig. 4). The increased intensity exceeded the capacity of the landscape to sustain it, rendering enterprises more vulnerable to the effects of drought.

The coincidence of record stock numbers and prolonged drought in the 1980s led to a well-documented episode of degradation in the Shire in the 1980s (McKeon et al. 2004). Social networks also changed. Transport and communications technology better connected pastoralists across greater distances and to more information (Ash and Stafford Smith 2003), and this technology also allowed for the long-distance temporary movement of cattle through emerging networks, which though commercial, relied primarily on social trust (McAllister et al. 2006a).

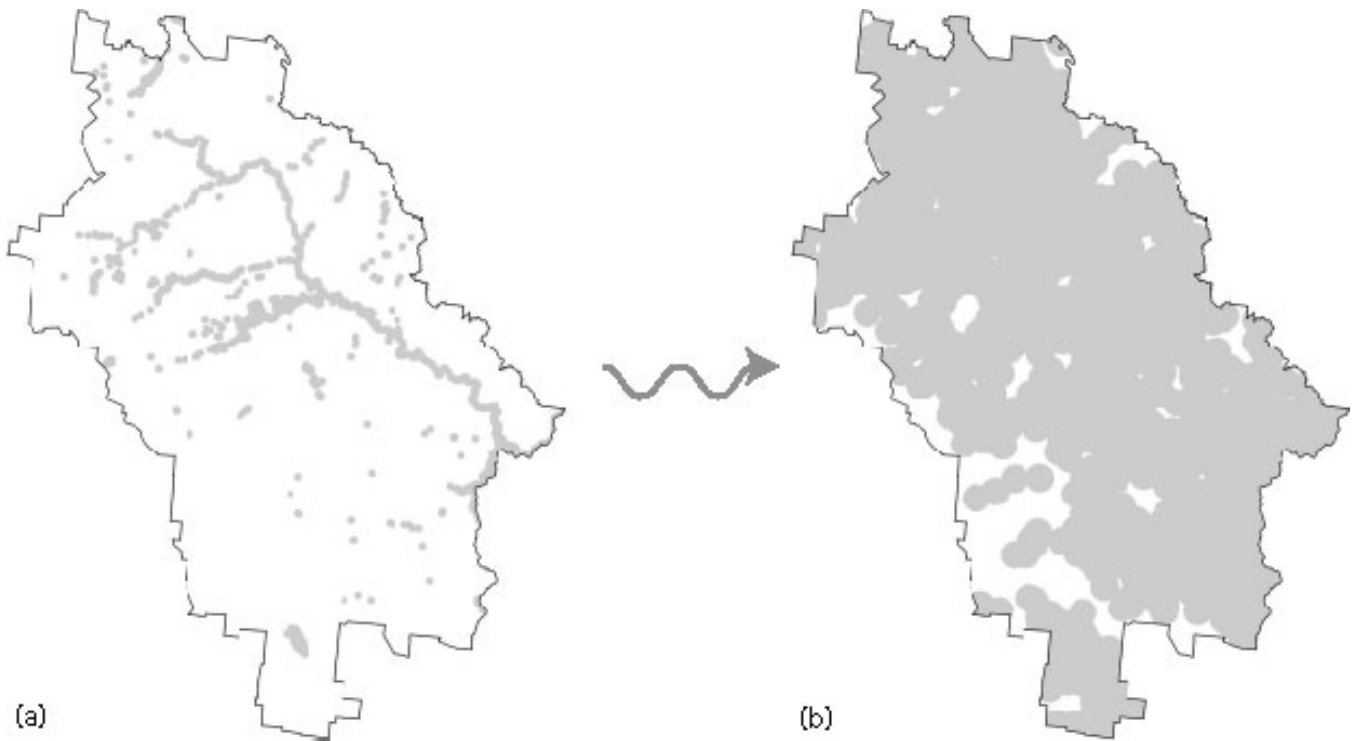
Through the reorganization stage, pastoralists' influence over policy continued to decline, and so linkages of individual properties to government changed (Fig. 5). Other pastoral system linkages also changed, with technological advances buffering the impact of climatic variability and changing the penetration of global media and

communication (Robertson 2003). Further, because pastoral-rural and urban institutions operate in different contexts, there is some tension between these scales of governance (Maru et al. 2007). Recently, there has been increased pressure on the pastoral industry in northeast Queensland to address the broader environmental consequences of their land management practices. This has arisen because the majority (over eighty percent) of terrestrial sediments and nutrients deposited in the Great Barrier Reef World Heritage Area originate from the extensive grazing lands of the Queensland interior (Furnas 2003). Catchment modeling indicates that hillslope erosion rates on grazing lands are 2-6 times greater than pre-European levels and that the quantity of sediments and nutrients lost from these grazing lands is strongly dependent upon grazing management practices (Gifford 1985). This has led to increasing pressures on graziers to change their management practices to decrease the off-property impacts (See Reef Plan, Queensland Department of the Premier and Cabinet).

### SYNTHESIS

Australians are now modifying their culture of land and water usage to be more in tune with the limitations of their environment (Diamond 2005). People and policy increasingly appreciate the fragile nature of Australian soils and the huge variability in water resource availability, and accordingly have broadened their evaluation of agricultural activity to include ecology and society. In the rangelands, adaptations are occurring within the boundaries of enterprises and regions, and through pastoralists' interactions with governments. New institutions will need to emerge that facilitate adaptation to the increasing exposure to the risks associated with globalized markets, which are distorted by subsidies, and the growing broadscale challenges in rangelands, such as catchment to national-scale solutions to maintaining ecosystem services and biodiversity, accommodating Aboriginal interests, and climate change. To do this, the new institutions will need to foster more widespread interaction among pastoralists and other rangeland stakeholders. At these broad scales, the drivers of change and adaptive responses to them are inextricably linked: the social, institutional and biophysical constraints and challenges that face pastoralists today, have been strongly shaped by the aggregate history of actions and adaptations in the past.

**Fig. 4.** Grazing land use fragmented by distance between waterpoints (from Abbott and McAllister 2004). (a) Pastoral pioneers in the Dalrymple Shire encountered disconnected fragments of useable land with access to natural water sources. (b) gradually land use expanded and became more connected by the introduction of man-made waterpoints and cattle breeds able to venture further from water.



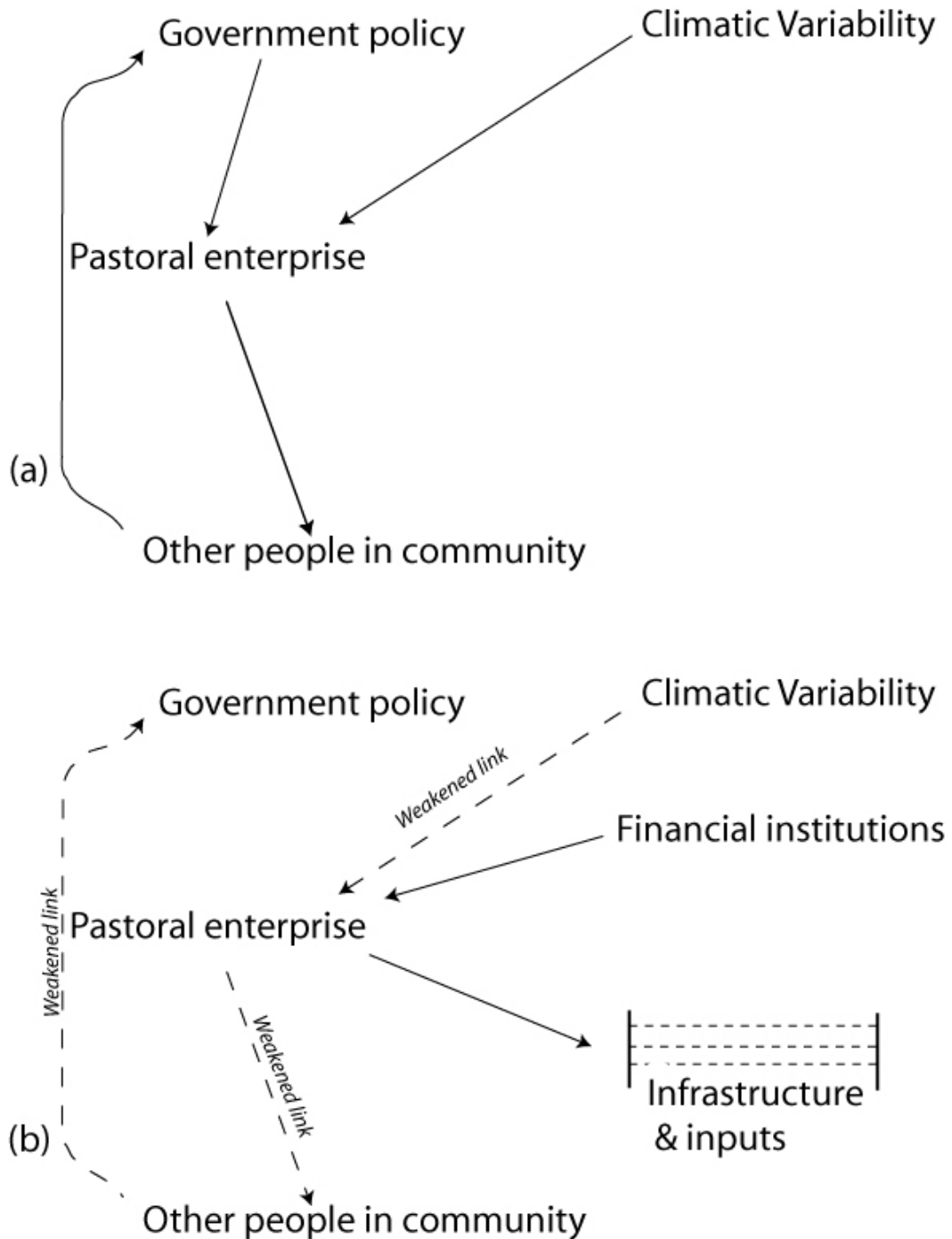
Changing social, environmental, and economic drivers will test the resilience of Australia's pastoral systems at various scales. The ability of practitioners to prejudge responses to major stress is not only critical to managing the rangelands, but also to the credibility of resilience as a theory. Without testing resilience as a framework, we have used it in this paper to help summarize a history of adaptation.

A system can only function when its keys objects and processes are linked, for example, a market cannot function unless supplying and demanding objects are connected. Cumming et al. (2005) call this structured description of a system an identity. A more formal view is that systems can be represented as networks and can be analysed accordingly, and that network metrics may illustrate resilience (Janssen et al. 2006). We are some way from formally defining how network analysis may

prejudge system resilience. We can, however, frame our system as a network and consider what change to its structure would lead to better longer-term outcomes, and where this will leave the system in terms of its adaptive cycle, keeping in mind that a "release" is seen as major change in the system's network/identity. The resilience of individual pastoralists and their enterprises will differ significantly. We propose that these differences can be analyzed by examining an individual's links to their financiers, their own environmental conditions, their social and kin connections, and their options for change, and past adaptation can be summarized along these lines:

1. Pastoralists are more connected and less reliant on hubs: Pastoralists in Australia are more densely connected than ever. Post 1950s, property sizes in northeast Queensland

**Fig. 5.** Changes in a pastoral enterprise's identity in response to 1960-1970 stress. (a) shows a "pre-release" enterprise with strong links to government, variability, and community. (b) shows the enterprise "post-release" with reduced links to government, community, and variability, and stronger links to financial institutions and the infrastructure needed for intensified production.



have become larger and less labor dependant, so population densities have dropped, but communications and transport technologies have removed their isolation from the rest of Australia and indeed the world, which may homogenize Australian social norms (McAllister and Reeson, *unpublished manuscript*). In the past, physical structures, e.g., church, town, pub, etc., meant that communication often occurred through hubs of activity. The nature of modern day communication and information flow has reduced the reliance on these hubs, possibly reducing local connectivity and affecting the mix between strong and weak connections (Newman and Dale 2005, Bodin et al. 2006). According to the review by Janssen et al. (2006), dense social networks may facilitate better information exchange, but may also become brittle; specialized locally adapted knowledge may be replaced by inappropriate knowledge from elsewhere.

2. Pastoralists have weaker links to the environment: The drive to intensify production has seen the introduction of artificial waterpoints, supplementary feed, and breeds less prone to mortality in drought. All of these buffer the impact of climatic variation and weaken environmental feedbacks, which can be further weakened by drought relief. This weakening of environmental feedback is what we interpret as weaker pastoral links to the environment. Whilst these may be a short-term fix, environmental degradation (Gordon, *in press*), particularly of key resources (Illius and O'Connor 1999) can lead to system collapse in the long run, whereby a collapse we mean a change in the key links and processes which define the system's identity.
3. Pastoralists have stronger links to alternate land uses, but weaker links to governance. Demand from other would-be users of the rangelands has created a market for alternative land uses. Some alternatives, such as tourism, amenity, and ecosystem services, can be delivered by adapting existing rangeland enterprises to produce these services.

Periurbanization (Ford 1999) and the complete destocking of rangelands for conservation are examples in which the existing regime is replaced by something altogether different. It is the decreasing importance of pastoral production relative to these alternative land uses that has somewhat reduced the political power of pastoralists in Australia, who still focus on livestock production. Reduced political power has weakened a previously very strong buffer against policy interventions that might usurp pastoral land uses.

Pastoralists have stronger links to global economy, and variable links to finance. Pastoralism has always been strongly linked to global prices of output and inputs (Robertson 2003). Declining margins, and an increased percentage of imported inputs and exported outputs, have seen the importance of such links increase (see Ash and Stafford Smith 2003, Robertson 2003), and greater competition from other suppliers of livestock products has changed Australian pastoralists from price setters to price takers. Debt levels link pastoralists to financial institutions. These links seem very important determinants of resilience, but strengths differ widely based on each enterprise's unique history. Also, with the decline in political power in the sector, interest rates, which determine the repayments on loans, are driven by broader political agendas rather than the need to maintain the viability of the agricultural sector.

As a landscape dominated by pastoralism, the resilience of Australia's rangelands is determined by the experiences of the pastoralists that comprise it. A thriving pastoral community would suggest resilience at the landscape scale, but change is inevitable, and a lack of resilience, and consequent "release" in pastoralism at one scale may be required to maintain resilience at another. For example, in many pastoral regions in Australia there is pressure to consolidate and increase the size of enterprises (Stokes et al. 2006); clearly some enterprises will survive at the expense of others, and there is likely to be a change from family-based pastoral enterprises toward pastoral companies. The latter is bound to change the strength of different linkages

in the pastoral sector, away from one based on friendships and relationships toward one driven by shareholders, many of whom may not be based in the rangelands or even Australia.

An extreme outcome of “release” is that pastoralism may need to disappear completely, in order to maintain Australia’s present-day key function and structure (i.e. resilience at a very coarse scale), however, this is unlikely to happen because of the vital role that pastoralists play in managing vegetation to reduce wildfires, and biosecurity and biodiversity issues related to the control of weeds and pests. In the future we expect pastoralists to be managing landscape, in part for livestock products and in part for the ecosystem goods and services rangelands provide. This latter role could be funded through incentives or stewardship payments, as they are in Europe (Cardwell 2003).

This paper has used the theory of adaptive cycles to analyze the history of rangeland Australia, where rapid change is now likely as environmental and amenity values increase. Understanding past adaptation is an important part of understanding and directing the future. We argue that changes occurring to the pastoral identity in Australia generally point to lower resilience: increased information flow and brittle social networks with greater opportunities to form new links to alternative land uses. Presently high cattle prices are masking that industry’s lowered resilience. Any pending release is likely to be positive for the region giving a great opportunity to change. Ultimately, pastoralism is likely to remain as the core activity in rangelands, but with a whole new set of linkages to post-production economy, information, and social networks, and to a more diverse group of land users.

Responses to this article can be read online at:  
<http://www.ecologyandsociety.org/vol11/iss2/art41/responses/>

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