level of legal protection for the grasslands is insufficient. Only four percent of the temperate grassland biome is under protected status, resulting in the lowest level of protection of the world's 14 biomes. The second concern is the challenge of managing temperate grassland in the face of widespread livestock grazing, the introduction of exotic species, fire management and the loss of grasslands through urban and forest encroachment. In addition, grassland conservation is threatened by the overarching, yet not well understood, impact of global climatic changes (TGCI 2008).

![Figure 5. Representation of taxa (a) and research themes (b) in temperate grassland conservation. Results obtained from a search of 78 publications that were published in international journals. Publication list retrieved from the Web of Science and individually searched for the presence of each category. Studies that addressed organic matter and chemical cycles are excluded from the top graph.](image)

![Figure 6. Proportion of literature (%) that addressed conservation research topics in native temperate grassland classified according to the continent where the study was conducted. The information is based on published literature found under the keyword search “temperate grassland conservation” at the Web of Science.](image)

### Identifying the Gaps in Native Temperate Grassland Conservation Research

Conservation research is one important tool that is essential for defining management prescriptions and for the identification of the relationship between the biota and the application of management under various conditions (climatic conditions, intensive management). To set future conservation research priorities it is important to identify key gaps in knowledge. To do this we examined 78 international publications that matched with the keyword search ("temperate grassland conservation") in the Web of Science and were published between 1990 and 2010. Based on its content, each publication was assigned to preselected research themes and the broad taxonomic group of the organism under study. Studies that address two or more topics were classified to two or more categories. The assignment of publication to research themes revealed a major focus of research on plants and birds (Figure 5). Despite their recognised contribution to biodiversity in grasslands, invertebrates were widely underrepresented in this literature. Less than 10 percent of all studies focused on invertebrates in temperate grassland conservation research. Most of the ecological studies that we examined were related to management, conversion and modification of grasslands (Figure 6). Surprisingly, topics such as climate change and invasion were scarcely addressed. We also compiled information from the TGCI report to further identify future conservation research in temperate grasslands at the global scale (TGCI 2008). Based on information provided by experts on temperate grassland conservation it was clear that considerable insight into temperate grassland ecology and the effects of climate change, invasion and management has
been gained from North America and to a much smaller extent from Australia and South Africa (Figure 6, Table 1). In North America and Asia long-term ecological monitoring programs are established, however, in Australia, South America and South Africa there appears to be a lack of any coordinated monitoring program (TGCCI 2008). All temperate grassland experts from the World Temperate Grassland Conservation Initiative agreed on the fact that all regions of native temperate grasslands experience a low public awareness (with the exceptions of the North American prairies) and increasing "public environmental education" is needed (Table 1). The development of mechanisms for improving the international collaboration related to temperate grassland conservation was identified as one major global strategy for future temperate grassland conservation (TGCCI 2008). This can be achieved through multidisciplinary research networks that assist in gaining insight into ecological patterns and processes in temperate grasslands. Collaborative efforts will lead to a better understanding of the ecology of temperate grassland and such approaches should be developed and expanded to regions where such networks do not exist. The establishment of networks of monitoring and research sites in temperate grasslands as demonstrated by the LTER monitoring scheme (http://www.hernet.edu) provides great opportunity for developing an understanding of ecological processes in temperate grasslands over long temporal and broad spatial scales. Although aspects of the ecology of some temperate grassland ecosystems are reasonably well understood (e.g. in North America), temperate grasslands in other regions such as in South Eastern Australia, South Africa and South America still lack up to date species inventories and basic ecological information (Table 1). The lack of taxonomy for many species, in particular for invertebrates, is the greatest impediment for collecting information of the species composition in temperate grassland. Similar challenges involving the lack of species inventories also face tropical ecosystems in remote areas that are often considered as biodiversity hotspots. However, studies in tropical ecosystems that include the knowledge of indigenous people and experienced citizen scientists have assisted greatly with the mapping of flora and fauna and have provided insights into the feasibility of such an approach (Stringer et al., 2003). Similar attempts to encourage and educate the people that live in and around temperate grasslands should play a much stronger role in the future of temperate grassland conservation at a global scale. In Australia, well advised community groups such as Friends of Grassland have made major contributions in this way (Richter et al., 2009).

CONSERVATION RESEARCH FOR NATIVE TEMPERATE GRASSLAND — WHERE TO FROM HERE?

Our overview indicates that native temperate grasslands throughout the world have been exposed to an extensive array of threats and human activities. These impacts will continue to alter the extent and quality of temperate grasslands to such a level that there is concern about their long-term viability. Thus, keys to improving the long-term survival of the temperate grassland are: (a) increasing legal protection; (b) the establishment of reserves that are large enough to maintain the diversity of habitats and species that are characteristic for the region; and c) a significant increase in conservation-related research to better understand the functioning of native temperate grassland that in turn will assist with the management and conservation of remaining grasslands (Bommar 2001; Martin & Wilsey 2006; Piper et al., 2007; Ries et al., 2001; TGCCI 2008). We found that there is an under representation of research that addresses the effects of the threats of climate change and biological invasion. Climate change and biological invasions are two major threats to the diversity and integrity of temperate grasslands. Research that contributes to our understanding of the ecological effects of climate change and bioic invasion, singularly and in combination, is essential to inform temperate grassland managers how to best maintain and manage grassland remnants. Such research will play an important role in shaping future grassland conservation — and is made more imperative with the growing evidence that climate change is a reality, and that there is considerable uncertainty about its direct and indirect effects. We found little information about the application and potential for rehabilitation and restoration of temperate native grasslands. This limitation leads to the need for action that targets the expansion of the size of native temperate grassland reserved areas and for the better protection of existing temperate grassland remnants. The rehabilitation of degraded areas that are contiguous with intact grasslands and the establishment of corridors and adequate buffers will play an important role in future temperate grassland research related to adaptive management. Several studies undertaken in the North American prairies show that at least some trial restoration of native grasslands has been successful (Vogel et al., 2007). Other attempts have had limited success (Pywell et al., 2002). In particular, combined approaches involving several different treatments such as species introductions and the reduction of dominant competitive species (invasive species) will be required for successful restoration of grasslands (Hobbie et al., 2003). It is acknowledged that restoration and re-vegetation are costly in labour and time and dependant on a particular range of environmental conditions and a high level of cooperation among government agencies, non-profit organisations and private landowners. However, such approaches will be paramount to achieving conservation of temperate grasslands in the future. Until we have established successful ways to rehabilitate and restore temperate grasslands, land managers and conservationists urgently require scientific evidence about the tolerable levels of grassland losses, fragmentation and degradation among a range of taxa and various scales prior to the application of adaptive management tools to prevent further declines in species and communities.

SYNTHESIS

Our review revealed that, at the level of individual taxonomic groups, invertebrates have been underrepresented in temperate grasslands research during the past decades. This is in stark contrast to their proportional occurrence in these grasslands. Thus, research focused on temperate grassland invertebrates should be given much greater consideration. There is an opportunity to study long-term effects on all taxa by aligning research programs with long term monitoring programs in temperate regions. This should assist in determining the level of impacts of environmental change on the grassland biota and on ecosystem functioning. Long-term observations over time and across landscape scales will provide a sound basis for detecting the generality in ecological questions, will assists in the assessment of biodiversity losses, allow early detection of changes, and aid in recognising the impacts of anthropogenic-induced climate change. Such findings are of enormous relevance to the broader community
and are essential for future conservation successes in native temperate grasslands (Parton et al., 1994). Clearly, regions where long-term monitoring has not yet taken place would benefit from the establishment of monitoring sites to record changes and to guide subsequent appropriate management. We conclude that to achieve effective conservation of native temperate grasslands a multiple approach involving legal protection, practical restoration, and adaptive management combined with applied research will be required. Balancing these priorities will be a future challenge in native temperate grassland research and can be overcome by integrating multi-disciplinary research that assists with the development of protection and conservation policies (Lemaire et al., 2005). Through such integrative research, an understanding of the resilience of temperate grasslands to historical and ongoing threats can be gained. Future temperate grassland research and conservation will be needed to be set in the socio-political and economic context that will drive human decision-making processes and lead to better on-ground conservation action. National and international networks and collaborations (such as the LTER network or the TGCI initiative) build suitable platforms to achieve such an inter-disciplinary approach and should be considered in future.

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