Planning for connections in the long-term in Patagonia

Establishing a long-term ecological research program and research collaborations in northwestern Patagonia. A workshop in San Carlos de Bariloche, Argentina, January 2009

The relict flora of Gondwanda, the mystic nature of the windswept Patagonian steppe, the Andes mountains and the southern beech forests, all combined, made San Carlos de Bariloche the perfect setting for gathering researchers from North and South America to discussa common goal:establishing a program of research and scientific interaction focused on long-term ecological questions in northern Patagonia. The 4-<l. workshop was funded by the National Science Foundation of the USA, and by the local scientific agencies of the Consejo Nacional de Investigaciones Cientfficas y Tecnicas (CONICET) and the Agencia Nacional de Promoci6n Cientifica y Tecnolgica (ANPCyT), and was led by Barbara Bond (Oregon State University, USA), Claudio Ghersa (Universidadd e Buenos Aires, Argentina) and Tomas Schlichter (Instituto Nacional de Tecnologfa Agropecuaria (INTA), Argentina). The meeting served as a rare opportunity to bring together a group of high-caliber scientists, ranging from population and community ecologiststo ecosystem ecologists, plant physiologists and hydrologists, all of whom had a keen interest in exploring the possibilitiesof developing an integrated research-program in the northern Patagonian region.

In the USA, the Long-Term Ecological Research (LTER) program was initiated in 1979-80 and currently has 26 active sites in various ecosystems in North America. As a result of the consistent funding support receivedfrom the National Science Foundation during this time frame, it has been possible to conduct studies at these sites with the intention of exploring long-term research topics that would be informative to the general scientific community. Mark Harmon (Oregon State University; USA) has been working within the LTER program from its inception and provided valuable insight into the lessons learned and pitfalls to be avoided in trying to develop a new long-term research program in the Patagonian region. For example, having an LTER program is not just about long-term measurements - for real success in a program, he suggested that research priorities must be directed around

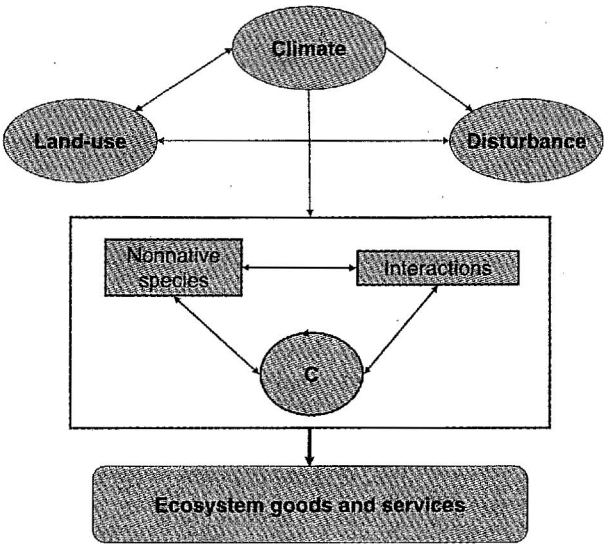

Fig. 1. Conceptual framework of priorities for long-term research in northern Patagonia, The combination of steep continuous environmental gradients of temperature and precipitation within a matrix of land-use change allows for the exploration of important impacts ofthe drivers of climate, land-use and disturbance in a range of ecosystems within the region. The introduction of nonnative species, novel interactions among species and trophic-level interactions, and the consequences for the carbon cycle, were identified as key topics that should be a focus of research for understanding the consequences of these drivers for ecosystem goods and services.

umbrella questions that link various ideas in a common long-term context. But the question put to the participants in the workshop was essentially this - is there the possibility of implementing an LTER program in Patagonia? The answer was a resoundingly hopeful yes, with extensive discussion to identify the initial steps required to create a conceptual framework, which would unite multiple disciplinary interests to address critical ecological questions for the region (Fig. 1).

How functionally vulnerable and resilient are Patagonian ecosystemsin the face of global environmental change and what are the consequences for ecosystem services?'

Gradients in all their glory

Northern Patagonia is unique: there was universal agreement in this workshop that one of the most outstanding features of the region is the steep orthogonal climatic gradients of temperature and precipitation. The combination of the influence of topography and consistent climatic patterns generates a gradient of decreasing rainfall from the Andean mountain range to the Argentinean Atlantic coast. In the region from 40° to *55°S,* there is a strong east-west precipitation gradient, with a shift in vegetation, in less than 150 km, from xeric desert shrubland to grass-shrub steppe, ecotones of forest-steppe leading to a low-stature tree cover and finally closed canopy forest (Austin & Sala, 2002). This rainfall gradient, combined with the latitudinal and altitudinal temperature gradients, provides the opportunity to examine a very wide range of ecosystems occurring in close proximity in a matrix of climatic conditions.

A second aspect of the region that is extraordinary is the evolutionary and biogeographic heritage of the flora and fauna in northern Patagonia. The links to austral (Gondwanan) floral species, including members of the Proteaceae and of the dominant *Nothofogus* species in Patagonian forests, demonstrates the evolutionary isolation of the region. Combined with th is heritage, evidence including congeneric relationships with existing tropical species and a frequent occurrence of plant-animal mutualisms suggest that much of the flora of temperate South America can be considered as a reflection of a warmer past with a neotropical history (Aizen & Ezcurra, 2008). As such, the interactions among species, and the response to global change, may be very different from those found in other regions of the world owing to the rare combination of biogeographic and historical events.

Fire, tree mortality and synchronized masting events

One of the clearest results to emerge from this workshop was that there is great potential for joining the scientific efforts of a number of co-existing research programs in the region, many of which already have an explicit 'long-term' focus. Infrequent events that occur over longer time frames can have important impacts on Patagonian ecosystems. For example, studies oflong-term drought effectson *Nothofogus* spp., carried out by Tomas Kitzberger'sr esearch group (Universidad Nacional de Comahue, Argentina), demonstrate that the vulnerability of tree mortality during drought events is a function, in part, of previous drought events (Suarez *et al.,* 2004). Studies of masting events in the long-lived monocarpic bamboo, *Chusquea culeou,* hich flowers every 60 yr, have shown that these masting events have important impacts on predator-prey interactions and on overstorey forest regeneration (Kitzberger *et al.,* 2007; Raffaele *et al.,* 2007; Giordano *et al., 2009).* In addition, periodic masting in dominant overstorey species, such as *Auracaria auracana* and *N obliqua,* highlight the importance of multiple-year studies for understanding tree demography in the region (Sanguinetti & Kitzberger, 2008). Finally, Tom Veblen (University of Colorado, Boulder, USA)

has been working in Patagonia for almost 30 yr and has carried out a range of studies demonstrating the importance of fire and of climate on stand dynamics in native forest species (Veblen *et al.,* 1999). The importance of fire and its interaction with human behavior emerged as a central focus for long-term research in the region, in particular as one of the modulators of ecotone boundaries.

Where did those pines come from?

In this region of Patagonia between 39° and 42°5, one of the dominant land-uses is afforestation of exotic species, which started in the *1970s* in areas ranging from arid steppe to native forest. Currently, there are over 70 000 ha under cultivation with various conifer species, principally *Pinus ponderosa* (> 90%) and, to a lesser degree, *Psuedotsuga menziesii* and *Pinus contorta* var. *latifoliada* (Laclau, 2003; Licata *et al.,* 2008). The current use of these plantations varies substantially and ranges from commercial exploitation of timber resources to maintenance of hunting and recreational habitats. Recent studies by the participants in the workshop have demonstrated substantial alterations of the hydrologic cycle as a result of pine afforestation in semi-arid ecosystems of the region (Fernandez *et al., 2008;* Licata *et al.,* 2008), carbon cycling (Nosetto *et al.,* 2006) and negative impacts on native animal biodiversity (Paritsis & Aizen, 2008). The current and future impacts of these plantations on biogeochemical cycles, including carbon sequestration, nutrient availability and biodiversity, were identified as a priority within the context of the long-term research plan.

Novel interactions

The introduction, whether intentional (as in the case of pine afforestation) or not, of a number of nonnative species, has had important impacts on the ecosystems in the region. While the effects on particular ecosystem processes or characteristics ate important, a research priority emerged for this region that focused not only on the impact of the nonnative species, but on how these introductions affect interactions among species and trophic levels. For example, the research group of Marcelo Aizen (Universidad Nacional de Cornahue, Argentina) recently demonstrated that the invasion of alien mutualists in the mesic forests of the region weakened the strength of the mutual isms among plants and their pollinators (Aizen *et al.,* 2008). Another recent study demonstrated a different type of interaction, that of the relationship between the litter of overs tory trees and their decomposers, where an affinity exists such that decomposition of 'home-site' litter is faster than in other microsites in the forest (Vivanco &; Austin, 2008). These unique interactions among species, and their potential disruption, were identified as a key vulnerability of these Patagonian ecosystems to human-induced global change.

The potential for novel human interactions was also a primary goal of this workshop. Elizabeth Borer (Oregon State University, USA) suggested that another part of the long-term research effort could be a link to their global-scale effort to establish common nutrient-manipulation experiments in grasslands worldwide (URL: hrtpi//www.science.oregonstate.edu/~seabloom/nurnet/). The Nutrient Network (NutNet) is a low-cost collaborative research effort to address the questions of nutrient limitations and their effects on biodiversity within a co-ordinated research network currently comprising more than 40 grassland sites worldwide.

The will and the way

The central research question that arose from the animated discussions was directed towards understanding and predicting the vulnerability and resilience of northern Paragonian ecosystems to global environmental change (Fig. 1). Within this scientific context, however, one must include the human dimension - not only its impact on ecosystem goods and services, but also the importance of human-induced changes in the environment. Given this positive launch of the idea of a long-term collaborative research program in the region, what is needed now is a network of interested researchers and funding opportunities, to identify future directions for establishing research networks and collaborations within the region.

The critical challenge is not the will, or the scientific potential, but the way in which an LTER program could be implemented in the region. It is difficult to obtain long-term funding for any research program, and this is more so in Argentina, where funding cycles can be erratic and consistent support over time is not guaranteed. What is clearly needed is a marshalling of resources, using multiple strategies from both national and international sources. The potential benefits of this endeavor are many and can be measured at multiple levels: (1) the gathering and dialogue of researchers with common scientific interests of conservation of natural resources in the region; (2) the potential for interactive research "networks that increase the value and impact of individuals working in the area; (3) the possibility of a focal point for international scientists to participate in research projects with insights and analytical tools that are not currently available; and (4) the establishment of long-term connections among local Patagonian researchers, students, and national and international institutions. Finally, the hope is that this initiative could serve as an inspiration for other similar programs within Argentina and South America.

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