Impacts of Invasive alien species on biodiversity

Llewellyn C. Foxcroft
Invasive Alien Species, Skukuza, KNP.
2002-11-15

The impacts of invasive alien species (IAS) are frequently referred to by numerous authors worldwide. Although there are numerous examples, only a few have been cited to provide a short preview of the potential impacts that biological invasions may have on biodiversity. By no means comprehensive, the flowing serves to indicate the impacts of IAS on different components of biodiversity and the seriousness of these impacts.

In order to understand the impact of biodiversity, one needs to consider a comprehensive definition of biodiversity. Biodiversity is made up of three facets, namely, functional, compositional and structural diversity (Noss, 1990). Compositional diversity (number of different species in a system) is most frequently accepted as a measure of biodiversity. However, functional (system functions such as water provision, water filtering and cleaning, water retention, flood prevention) and structural diversity (structural component of a system may be composition of grass and woody layers; old growth forest and under story components etc) are an integral part of the systems dynamics, and are frequently severely altered by biological invasions. IAS impacts are frequently recorded to affect more than one facet, or where one facet has been impacted upon, the others feel ripple effects. These impacts include replacement of diverse systems with single (or mixed) species stands of aliens, alteration of soil chemistry, alteration of geomorphological processes, alteration of fire regimes, alteration of hydrology, invasions leading to extinction of compositional diversity and the direct threat to indigenous fauna (Cronk & Fuller, 1995). Further, Richardson *et al*. (1997) suggested that the destruction of riparian habitats in Southern Africa is a key impact. Other aspects that have been noted are displacement by direct competition, reduced structural diversity, increased biomass production and disruption of the prevailing vegetation dynamics (van Wilgen & van Wyk, 1999). Although it may be argued that IAS enrich compositional diversity by adding new and diverse taxa to an area, Richardson *et al*. (1989) note examples where alien plant invasions have directly resulted in the extinction of a few species in southern Africa. Documented reports on the impacts of invasive alien species on biodiversity and ecosystem functioning (D'Antonio & Vitousek 1992; Richardson 1998), displacement of native species (Walker & Vitousek 1991; Holmes & Cowling 1997; Kwiatkowska *et al*. 1997), and modification of disturbance regimes and post-disturbance community dynamics (Mack & D'Antonio 1998) are numerous.

Higgins, Richardson and Cowling (2000) report on the transformation of ecosystems, where systems are completely transformed from previous states, to a state which is altered functionally, structurally and compositionally. The impacts of biological invasions are so widespread and significant that they are a recognised component of global change (Vitousek, *et al*. 1996). The invasion of American rangelands by *Bromus tectorum* has increased the frequency and intensity of fires, thereby transforming shrub lands into grasslands (Whisenant, 1990). Similarly the invasion of alien grasses into Californian chaparral has resulted in more frequent and intense fires, which in turn have altered species composition (Zedler *et al*. 1983). Plant invasions can also alter nutrient cycling patterns as illustrated by the invasion of the nitrogen-fixing shrub *Myrica faya* on volcanic surfaces in Hawaii (Vitousek and Walker, 1989). Hydraulics and hydrology can also be influenced, for example by *Melaleuca quinquenervia*, which raises soil elevations and thereby has influenced the hydraulics of Florida wetlands and the invasion of *Pinus* spp. in South African fynbos has dramatically reduced the water yield of catchments. Impacts of plant invasions on biodiversity composition are well illustrated by the example of invasion by *Mimosa pigra* in northern Australia, which is predicted to lead the collapse of plant and animal populations (Braithwaite *et al* 1989). In South Africa, the invasion of the fynbos by many *Acacia* species threatens many plant species, many of which are endemic (Musil, 1993).

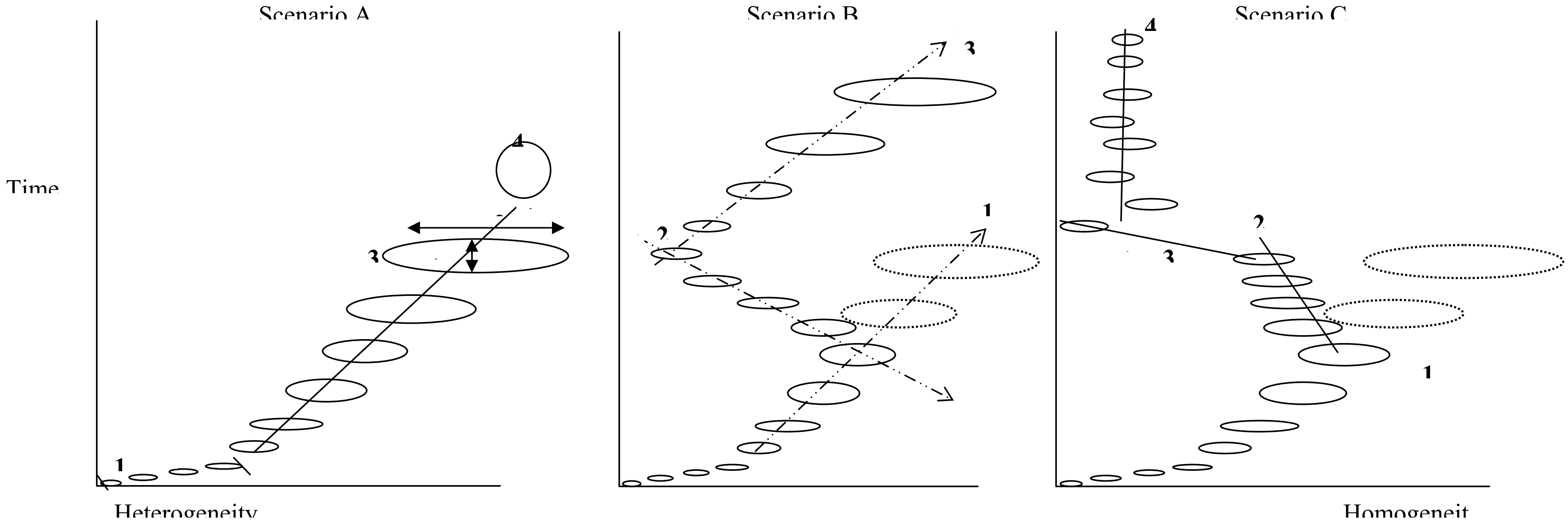
Bright (1999) showed how the introduction of an alien fish directly was attributed to the loss of more than 200 cichlids in Lake Victoria. Later, compounded by the arrival and rapid invasion of hyacinth, the whole Lake system collapsed, and with it the ecosystem around the Lake.

IAS are also reported to remove "keystone species" which can lead to the collapse of a system. Further, they often introduce a new "keystone species", which can alter the future dynamics of a particular system completely (Baskin, 2002).

Freitag-Ronaldson & Foxcroft (In press) indicate the long-term tendency of invasions to impact on system heterogeneity (or similarly biodiversity), over space and time. If left unchecked, invasive species exhibit abilities to move ecological systems from natural heterogeneity to homogeneity over a large scale and timeframe. Systems are driven towards ones that are uniformly homogeneous, either dominated by single species or invasive species associations, over wide areas representative of the area available to those particular species or associations. In contrast, species designated as serious alien impact invasives (i.e. transformers and others) which are controlled effectively should be able to be suppressed to maintenance levels with minimal tolerable impact – effectively staying within or being reversed back to the lag-phase condition (figures 1). However, species not controlled will be left to fluctuate as environmental conditions dictate. These fluctuations may rotate from scattered infestations to locally dense infestations which may for a short time cause a moderate to severe impact and then be removed or replaced by other species, hopefully before long-term irreversible impacts are caused.

Aquatic weeds can affect the plants beneath them by forming thick mats which eliminate submerged plants and algae, prevent photosynthesis and block oxygen diffusion from the air, causing the system to become anaerobic (Gopal, 1987). Decreased oxygenation of the water has been shown to significantly decrease the benthic invertebrates (Gratwicke & Marshall, 2001).

Figure 1 (from Freitag-Ronaldosn & Foxcroft, in press): Trend of plant invasion over time and space, with fluctuations between heterogeneity and homogeneity. (1) "lag-phase", (2) trend-line (tending towards 4), (3) invasion covers a wide area as a homogenous stand, but can fluctuate within certain parameters on a local or heterogeneity scale, (4) "new" transformed system with homogeneous stand of invasive plants over a wide area with little fluctuation in homogeneity (fluctuation would have little impact due to propagule pressure and the seed bank in the entire area); (b): Trend of plant invasions over time with mechanical and chemical control options. (1) trend-line heading for transformed state, (2) implementation of mechanical/chemical control operations, (3) trend towards altered state due to operations stopping for any reason.; (c): Trend of plant invasion over time with the release of effective biological control agents. (1) introduction of biocontrol agent, (2) establishment of biocontrol phase, (3) rapid collapse of host plants, (4) tending to central point of fluctuations through seasonal variations, of low impact and densities of host plant. Circles represent the third dimension, namely spatial scale or extent.



References:

BASKIN, Y. 2002. A plague of rats and rubbervines: The growing threats of species invasions. Shearwater Books/Island Press, Washington, D.C.

BRAITHWAITTE, R.W., LONSDALE, W.M., AND ESTBERGS, J.A. 1989. Alien vegetation and native biota in tropical Australia: the impact of *Mimisa pigra*. Biological Conservation 48: 189-210.

BRIGHT, C. 1999. Life out of bounds; bio-invasions in a borderless world. The World Watch Environmental Series. Earthscan Publications Ltd, London.

CRONK, Q.C.B & FULLER, J.C. 1995. Plant invasions: the threat to natural ecosystems. Chapman & Hall, London.

D'ANTONIO, C.M. & VITOUSEK, P.M. 1992. Biological invasions by exotic grasses, the grass/fire cycle an global change. Ann. Ev. Ecol. Syst. 23, 63-87.

FREITAG-RONALDSON, S. & FOXCROFT, L.C. In press. Anthropogenic ecosystem impacts in the Kruger National Park. Proceedings: The Kruger Experience- ecology and Management of savanna heterogeneity.

GOPAL, B. 1987. Water hyacinth. Aquatic plant studies 1. Elsevier, Amsterdam.

GRATWICKE , B. AND MARSHALL, B.E. 2001. The impact of *Azolla filiculloides* Lam. On animal biodiversity in streams in Zimbabwe.

HIGGINS, S.I., RICHARDSON, D.M. AND COWLING, R.M. 2000. Using a dynamic landscape model for planning the management of alien plant invasions. EcologicalApplications, 10(6). Pp1833-1848.

HOLMES, P.M. & COWLING, R.M. 1997. The effects of invasion by Acacia saligna on the guild structure and regeneration cacabilities of South Africa. J. Appl. Ecol. 34, 317-332.

KWIATKWSK, A.J., SPALIK, E. MICHALAK, A. & PANUFNIK, D. 1997. Influence of the size and density of *Carpinus betulus* on the spatial distribution and rate of deletion of forest flood species in the thermophilous oak forest. Plant ecol. 129, 1-10.

MACK, M.C. & D'ANTONIO, C.M. 1998. Inmpacts of biological invasions on disturbance regimes. TREE 13, 195-198.

MUSIL, C.F. 1993. Effect of invasive Australian *Acacis* on the regeneration growth and nutrient chemistry of South African lowland fynbos. Journal of Applied Ecology 30: 361-372.

NOSS, R.F.1990. Indicators for monitoring biodiversity: a hierarchical approach. Conservation biology, 4: 355-364.

RICHARDSON, D.M. 1998. Forestry trees as invasive aliens. Conserv. Biol. 12, 18 -26.

RICHARDSON, D.M., MACDONALD, I.A.W. & FORSYTH, G.G. 1989. Reductions in plant species richness under stands of alien trees and shrubs in the fynbos biome. South African Forestry J. 149:1-8.

RICHARDSON, D.M., I.A.W. MACDONALD, J.H. HOFFMANN, AND L. HENDERSON. 1997. Alien plant invasions. Pages 535-570 *in* R.M. Cowling, D.M. Richardson, and S.M. Pierce, editors. The vegetation of Southern Africa. Cambridge University Press, Cambridge, UK.

VITOUSEK, P.M., D'ANTONIO, C.M., LOOPE, L.L. AND WESTBORRKES, R. 1996. Biological invasions as global environmental change. American Scientist 4: 468-478.

VAN WILGEN, B.W., AND E. VAN WYK. 1999. Invading alien plant in South Africa: impacts and solutions. VIth International Rangeland Congress Proceedings Vol.2.

WALKER, L.R. & VITOUSEK, P.M. 1991. An invader alters germination and growth of a native dominant tree in Hawaii. Ecology 72, 1449-1455.

WHISENANT, S.G. 1990. Changing fire frequencies on Idaho's snake river plains: ecological and management implications. Pages 4-10 in E.D. McArthur, E.M. Romney, S.D. Smith and P.T. Tueller. (Eds). Proceedings of the symposium on cheatgrass invasion, shrub-die off and other aspects of shrub biology and management. Intermountain research station, forest service, US Department Agriculture, Ogden Utaha, USA.

ZEDLER, P.H., GAUTIER, C.R. AND MCMASTER, G.S. 1983. Vegetation change in response to extreme events: the effect of a short interval between fires in California chaparral and coastal scrub. Ecology 64:809-818.