CAWS Oration
Invasive alien species – are we up to the challenge?

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Summary The numbers of invasive species, and the economic and ecological damage they are causing throughout the world, are staggering. Unfortunately all factors that are leading to the success of invasive species are increasing. We need to develop a concerted global mechanism to deal more effectively with these trends.

Keywords Global changes, invasive species, policy options.

WHERE ARE WE?

During the past 50 years there have been enormous changes in the global environment. The recently completed Millennium Ecosystem Assessment (2005a) concluded that during this period we have 'changed ecosystems more rapidly and extensively than in any comparable period of time in the history of human history'.

What exactly are some of these changes and how do they relate to the concerns of this meeting? In 1950, the world population was 2.6 billion people; it is now 6.4 billion (US Census Bureau 2006). The land devoted to annual crops, our main food supply, stayed relatively constant during this period, expanding from 1.2 to 1.4 billion ha although the land utilised for permanent crops increased from 89 million in 1961 to 138 million ha.

The increased food supply to feed the growing population came from, to a large degree, the increased use of fertilisers; 13 million metric tons of nitrogenous fertilisers in 1961 to 88 million tons in 2002 (FAO-STAT 2006). Other important changes have occurred that have a large impact on the earth's biota. There have been significant changes to the composition to the earth's atmosphere with the CO_2 concentration growing from 316 ppm in the late 1950s to the present 377 ppm (Keeling and Whorf 2005). A major global change has been the increase in the wealth of nations and the enormous global trade that supports the growing affluence of many parts of the world. Although the population has doubled between 1950 to the present, the global GDP has grown six fold and the global trade in merchandise 10 fold (Figure 1). So, the impact per capita on the drivers of global changes is steadily increasing.

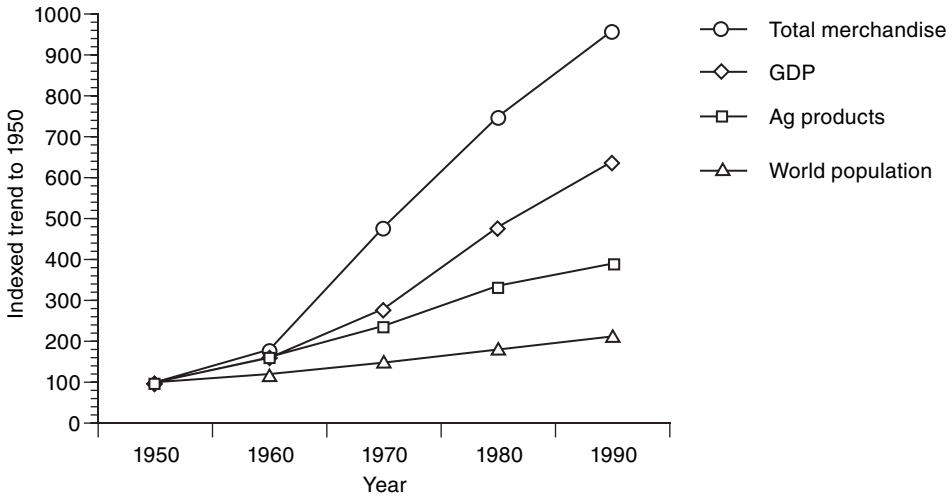

Figure 1. Comparative increase in global total trade in merchandise and agricultural products, world human population and GDP indexed to 1950. (Data from WTO 2003, 2005 and US Census Bureau 2006).

WHAT HAS BEEN THE RESULT?

In most regions of the world, the numbers of invasive alien species (IAS) are substantial (Vitousek *et al.* 1997), and in some places such as Hawaii they have an overwhelming presence. The US has documented a steady increase in successful invasions of all taxonomic groups during the last century (US Congress 1993) and there is evidence of an increasing tempo of invasions in marine systems (Cohen and Carlton 1998). The causes of these introductions are both purposeful, as is the case with many plants, and accidental, in the case of most insects (Lonsdale 2002). The potential for new introductions has by no means been saturated; for example, 22,000 plant species are thought to be capable of becoming IAS in addition to the 4000 species that already have (Rapoport 1991). If one considers species groups such as arthropods, the numbers of potential invaders become much greater (Pimental *et al.* 2001).

This massive biotic exchange has caused considerable disruption in many of the world's ecosystems because of the inordinate success of some of these invaders. Some of these species have altered fire and water regimes, caused multiple extinctions and extirpations, disrupted agriculture and fisheries, and rendered some systems, such as tropical rivers, difficult for navigation (Mooney 2005). Many invaders cause enormous economic as well as ecological damage (Zavaleta and Royval 2000, Pimentel *et al.* 2001).

It is now easier to appreciate the increasing recognition of what invasive species are doing in various parts of the world by tracking the regional news services as noted in the following that appeared in a relatively short period of time in United States newspapers:

- 'Of aquatic invasive species in Indiana, it's estimated that 30 percent have been introduced in just the past 30 years.' The Journal Gazette, Fort Wayne, Indiana. April 30, 2006.
- 'The US House of Representatives is looking at a $2 million budget initiative to kill off Cape Coral's monitor lizards and other invasive species in Florida.' Southwest Florida, The News-Press. May 1, 2006.
- '$4.9m approved for coqui fight. A state team will go to Puerto Rico to seek biological controls.' Star Bulletin (Hawaii). May 16, 2006.
- 'Paterson's curse has been found at two locations in Oregon. Early detection of the noxious weed and rapid response by the Oregon Department of Agriculture has kept it manageable at this point.' MedfordNews.com. May 19, 2006.
- 'Last week, the discovery of emerald ash borer here sent residents seeking ways to protect what trees they could and to pay for removal and replacement of those that are doomed. The onslaught seems unending; the battle at times overwhelming.' Kalamazoo (Michigan) Gazette. Sunday, May 21, 2006.
- 'If only it took as long for an invasive species to gain a foothold on the Great Lakes as it does for Congress to deal with an issue, we wouldn't have to worry about the quagga mussel'. The Sheboygan (Wisconsin) Press. May 23, 2006.
- 'Invasive species threaten an estimated $170 million in crop production in upstate New York, Sen. Charles Schumer said Wednesday.' Binghamton (New York) Press and Sun-Bulletin. May 25, 2006.

What can be gained from reading these is that the general public is certainly being informed about invasive species, the considerable costs to contain them, the value of early detection, the slow political process that deals with them and the unending battle they represent. Also noted in the content of these stories and others not cited for this period, is that many of the invasives of considerable concern are very recent, and in essence new players, and that something unusual is happening: the tempo of invasions is increasing.

WHERE ARE WE GOING?

Part of 'something unusual' is that there has been dramatic changes, as noted earlier, to the driving forces that influence the pace and tempo of the movement and success of invasive species. What do we expect of these forces of change in the future; are things going to get better? No; not according to trend lines or to scenarios (Millennium Ecosystem Assessment 2005b). Models predict that we will see higher maximum temperatures, fewer frost days and more hot days. Precipitation events will be more intense. Atmospheric CO_2 concentrations will most like double by 2100, and by 2050 global trade in grains will increase by three times. Nitrogen fertiliser demand could also double by 2050 by many scenarios. Land use change will continue with particular large amounts occurring in developing countries due to deforestation and the addition of agricultural landscapes. All of these changes will have a direct and generally positive impact on the success of pests and invasive species in general (Dukes and Mooney 1999, Mooney and Hobbs 2000).

WHAT WILL BE THE CONSEQUENCES?

1) Global trade Global trade is becoming recognised as the dominant driver of the increasing numbers of invasive species becoming established around the world. Ruiz and Carlton (2003) have provided a very

useful analysis of how we can better understand, and hence regulate, the complex chain of events in the movement of organisms from one biogeographic region to another, including the frequency, size, duration of the transfer and the number of commodities being moved, their source regions and the number of recipient regions. The nature and complexity of trade routes are continually changing in the world, regulated by the World Trade Organization. The modes of transport are getting bigger and the cargos larger. Countries like China have had explosive trade expansion with a great number of countries and now dominate imports to such countries as the United States (Jenkins and Mooney in press). Along with these changing patterns, we are seeing new invasives entering both source and sink nations. In the case of China and the US we are seeing exchanges such as the American White Moth (*Hyphantria cunea*), which arrived in China in 1979 and is now subject to a massive control effort there since it is a threat to the 'green' Olympics in Beijing, and the Asian longhorned beetle (*Anoplophora glabripennis*), which arrived in the United States in 1996 and is rapidly becoming a serious pest to native and cultivated trees.

2) CO_2 increase A number of recent studies have shown that some rather devastating invasive species are favoured in a richer CO_2 environment and in some cases in unexpected ways. Enriched CO_2 favours a pervasive and destructive invasive grass (*Bromus madritensis* L. ssp. *rubens*) in the deserts of the south-west US, but most markedly under high rainfall years (Smith *et al.* 2000). Similarly, experiments indicate that rising CO_2 concentrations are an important contributor to the increasing success of the spread of a native invasive species (*Prosopis glandulosa* Torr. var. *glandulosa*) that now dominates millions of ha, also in the US south-west (Polly *et al.* 2002). In an example from South America, experiments have shown that enhanced CO_2 concentrations are favouring invasions of African grasses (*Hyparrhenia rufa* (Nees) Stapf and *Melinis minutiflora* P.Beauv.), which are displacing natives and converting savannas to pure grasslands and altering fire regimes (Baruch and Jackson 2005).

3) Nitrogen deposition The human alteration of the nitrogen cycle is of an enormous magnitude due to industrial development including the direct synthetic production of nitrogen fertilisers. Like CO_2, nitrogen is a powerful growth stimulus for plants. Nitrogen being deposited into natural systems is causing changes to the dynamics of ecosystems. N deposition is predicted to double in amount by 2050 (Millennium Ecosystem Assessment 2005b).

Quite often weedy species have fast growth rates and rapid leaf turnover, and are favoured under high nitrogen availabilities (Scherer-Lorenzen *et al.* 2000). As one of many examples that have been described, Weiss (1999) provides an illustration of how nitrogen enhancement through increased deposition is favouring invasive grasses in a California annual grass ecosystem. These grasses are outcompeting the native annuals including a major food source for an endangered butterfly species. Similar complex interactions are to be expected in the enhancement of N levels in host plants for insects, thereby increasing herbivory potential (Throop and Lerdau 2004) and in interactions related to changing fire regimes (Fenn *et al.* 2003).

4) Climate change The IPCC concluded that 'Changes in climatic variables have led to increased frequency and intensity of outbreaks of pests and diseases accompanied by range shifts poleward or to higher altitudes of the pests/disease organisms' (IPCC 2002). Changes in climatic extremes, hurricanes and flooding will also increase opportunities for invasive species. Forest diebacks, associated with northward range shifts of tree species, and droughts, exacerbated by increases in temperatures, will facilitate entry of invasives (Jones *et al.* 1994). We are just beginning to see the impacts of what most likely will be large disruptions of the fabric of extant ecosystems.

To the above drivers we could add land use change, a large influence on the successful establishment of invasive species.

WHAT IS BEING DONE?

It is clear that we have a major global crisis at present and with future trends showing increases in the intensity of the major drivers of the success of invasives the problem is only going to get worse. So what is happening now to mitigate these trends? There is an increasing intensity of awareness of the problem in many nations and effort to learn more about the issue, to share information and to mount action programs addressed at all links in the chain of success of invasives—from border controls to eradication of entrenched invasives. At the international level Article 8 of the Convention on Biological Diversity states that signatories of 'Each Contracting Party shall, as far as possible and as appropriate: (8h) Prevent the introduction of, control or eradicate those alien species which threaten ecosystems, habitats or species'. There are over 150 signatory nations to this convention, although not all have equal capacity to meet the challenges presented by this article. At the Fifth Conference of the Parties (COP) at The Hague in 2002, Decision V/8

was adopted outlining guiding principles dealing with invasive species and at COP VIII, in Curitiba, Brazil in 2006, Decision VIII/27 encouraged Parties of the Convention and other Governments to action related to 'gaps and inconsistencies in the international regulatory framework, that deal with a variety of issues, including pathway analysis, aquaculture, ballast water, tourism, pet trade'. At the forthcoming COP IX, an in-depth review will be made of ongoing work related to invasive species (http://www.biodiv.org/default.shtml). These actions represent a massive agenda that is taking place at the international level. Is it enough? No, we can do more.

WHAT CAN WE DO BETTER?

A road map is under development indicating the drivers of increasing invasive species and the sorts of things that we can do to stem them (Figure 2). This road map shows that changes that are taking place, how they enhance the introduction and spread of invasives, as well as where we can take actions to minimise the problem. A cartoon of the roadmap is illustrated as a balancing act between the increasing driver pressures and the actions that need to be taken.

There are actions in many countries to push this balance in the right direction. However, the forces of change are extraordinarily strong, such as climate change and the increasing world trade. The mechanisms for concerted global actions are weak, since they are built generally on best practices and have little regulatory or global actions associated with them, although there are promising developments regarding ballast water. It is generally agreed upon that the most cost effective approach to addressing invasive species is early warning and early action. We can surely do more in this realm. There have been calls for national centres for invasive species (Schmitz and Simberloff 2001) that would overcome overlapping mandates of agencies at the national, state and local levels. The invasives issue needs attention and action that can come from national centres, such as a national Centre for Disease Control that interacts with an international action body, such as the World Health Organization. Early warning and the means for early action should be a prime mandate for such a centre just as it is in emerging human diseases. The problems are the same; the means for action are not. We need to change this.

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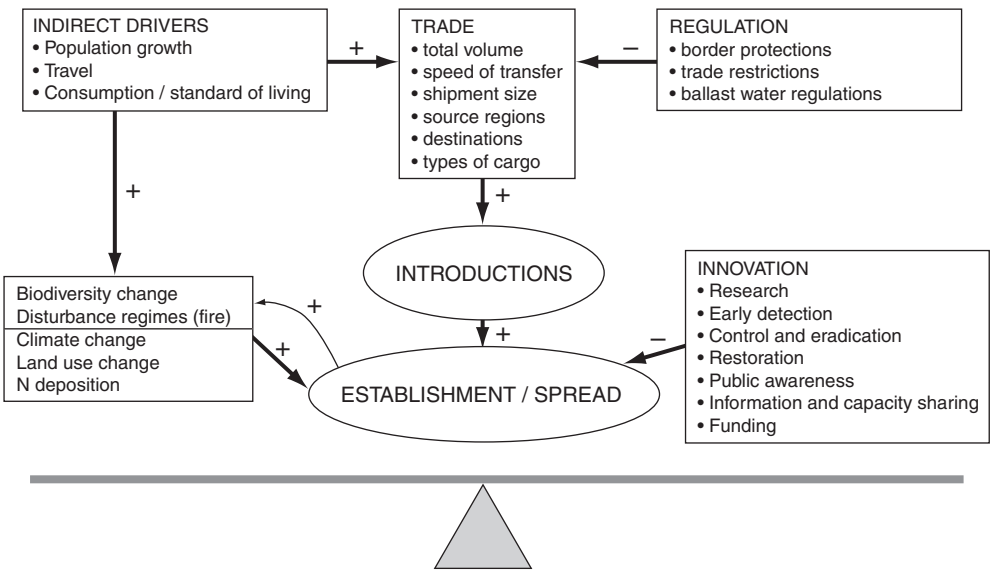

Figure 2. A balance showing the opposing forces leading either to a reduction or increase in the invasive species problem.

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