The Editors: an End has a Start

A significant landmark in raising awareness of biological invasions among the public and policy makers in North America was the publication in 1993 of the monograph *Harmful Non-Indigenous Species in the United States* (Office of Technology Assessment 1993). This sweeping document, published by the US Congress, presented the first continental assessment of the degree to which introduced species had spread across the USA, the breadth of ecosystems subsequently impacted by these species and the policy options available to government and managers. Arguably, this synthesis played a pivotal role in the subsequent signing of Executive Order 13112 "Invasive Species" by President Bill Clinton in 1999. The Executive Order placed responsibilities upon Federal agencies "to prevent the introduction of invasive species and provide for their control and to minimise the economic, ecological, and human health impacts that invasive species cause" (USA 1999). Furthermore, Executive Order 13112 established the National Invasive Species Council to oversee implementation and required the initiation of National Invasive Species Management Plans. What is probably startling about the impact of *Harmful Non-Indigenous Species in the United States* is that at that time information on invasive species was remarkably poor with a minimum estimate of the number of alien species with origins outside the USA being little more than 4,500, the majority plants and invertebrates. Yet, while imprecise, these figures identified significant gaps in knowledge and highlighted that even imprecise estimates were sufficient to raise alarm bells.

Fast forward 15 years and to the other side of the Atlantic where another landmark publication appears: the *Handbook of Alien Species in Europe*. In the intervening period much has changed in the global perception of biological invasions, now widely recognised as one of the major pressures on ecosystems (Nentwig 2007). Yet it is only now that Europe has the first continent-wide snapshot of the scale and impact of biological invasions from the Mediterranean Sea to the Arctic tundra. On this occasion data are more robust, drawn from systematic searches and peer reviewed by experts, yet the astounding figure of at least 11,000 introduced species is acknowledged as only a first approximation and an undoubted underestimate (Olenin and Didžiulis 2009). Nevertheless, a picture emerges that is as remarkable as it is worrying.

Biological invasions are not a new phenomenon to Europe. For example, Corsica has been invaded more than twenty times in the last 2,500 years, first by the Phoenicians (565 BC), then Etruscans (540 BC), Carthaginians (270 BC), Romans (259 BC), Vandals (AD 455), Byzantines (AD 534), Goths (AD 549), Saracens (AD 704), Lombards (AD 725), Pisanos (AD 1015), Genoese (AD 1195), Aragonese (AD 1297), Genoese again (1358), Milanese (AD 1468) Franco-Ottomans (AD 1553), French (AD 1768), British (AD 1794) and the German-Italian Axis during the Second World War (Hulme 2004). These human invasions brought in their wake species from other parts of the world, either

intentionally or by accident. Biotic homogenisation in Europe has probably been occurring over millennia, yet the long history of human invasion and trade blurs the distinction between native and alien species. Thus the origin of many species introduced in historical times is uncertain and especially so for marine ecosystems, where often the status and origin of species is unknown. Although this uncertainty frustrates analyses, it also indicates that many archaeophytes and archaeozoans have become integrated in native communities without clear evidence of detriment either to native species or ecosystem processes (e.g., Pyšek et al. 2005).

These historical trends should not encourage complacency regarding the ultimate impacts of invasive species. It is quite possible that recent introductions from outside Europe are likely to be more invasive than alien species that originate from another part of Europe (Lloret et al. 2004). The *Handbook of Alien Species in Europe* illustrates that for most taxa an increasing proportion of introduced species are from other continents, especially the Americas and Asia. Indeed, the trends in the cumulative records of alien species recorded in Europe reveal consistent increases with time (Hulme et al. 2009a). For example, on average 19 invertebrates (Roques et al. 2009), 16 plants (Pyšek et al. 2009) and one mammal (Genovesi et al. 2009) are newly introduced to one or more parts of Europe every year. These numbers may not sound especially threatening but for many taxa, recent rates are higher than those seen at the beginning of the 19th century indicating that the problem of invasions is not diminishing.

A clear signal is that global trade is a major driver of biological invasions in Europe. This is not surprising, since this signal is seen worldwide (Perrings et al. 2005). Accounting for the multitude of pathways by which an alien species is introduced is essential to disentangle the role of species and ecosystem traits in biological invasions as well as predict future trends and identify management options. The *Handbook of Alien Species in Europe* highlights that vertebrate introduction tend to be characterised as deliberate releases (often as game animals), invertebrates as contaminants of stored products or horticultural material, plants as escapes from gardens, while pathogenic fungi are generally introduced as contaminants of their hosts (Hulme et al. 2008b). Several major infrastructural projects linking together seas via freshwaters and canal networks in order to facilitate the movement of goods are a major source of introductions, for example into the Mediterranean from the Red Sea, and from the Caspian and Black Seas to the Baltic (Galil et al. 2009, Gherardi et al. 2009). Once introduced to Europe, species with tiny spores, such as fungi and bryophytes, may be able to spread across the continent without additional human assistance (Desprez-Loustau 2009; Essl and Lambdon 2009) and such unaided spread is likely to be the hardest to contain.

The anthropogenic signal on biological invasions persists after the initial introduction events in that even once established, many alien species remain associated with human modified ecosystems. Alien plants (Pyšek et al. 2009) and invertebrates (Roques et al. 2009) are proportionally more frequent in urban than semi-natural habitats, while birds and amphibians (Kark et al. 2009) as well as mammals

(Genovesi et al. 2009) are most frequently found in arable lands, gardens and parks. Clearly, in such habitats alien species are most likely to be perceived as having economic rather than ecological impacts. For example, in the UK alone, the cost to the timber industry of grey squirrel (*Sciurus carolinensis*) damage to beech, sycamore and oak is $15 million while two common grain contaminants, wild oat (*Avena fatua*) and field speedwell (*Veronica persica*), are significant agricultural weeds with annual costs of control running to $150 million (Williamson 2002). However, current appreciation of invasive species impacts on biodiversity in Europe is poor by comparison with North America (Levine et al. 2003 for plants, Roques et al. 2009 for invertebrates). This is evident in the percentage of species with known impacts recorded by the DAISIE (Delivering Alien Invasive Species Inventories in Europe) project that ranges from only 5% for plants, around 15% for invertebrates and marine taxa, to a high of 30% for vertebrates and freshwater species. These percentages most likely reflect the lack of information across large taxonomic groups but also the difficulty of quantifying subtle impacts on ecosystem processes.

So what are the response options to this worrying panorama? The *Handbook of Alien Species in Europe* provides generic information relating to management of particular taxonomic groups as well as more detailed information on control and eradication strategies for 100 of the worst species (Vilà et al. 2009). However such information is only of value if the mechanism for management and policy implementation exists. A key component of Executive Order 13112 in the USA was the establishment of a National Invasive Species Management Plan (USA 1999). The plan is focused upon five strategic goals: prevention; early detection and rapid response; control and management; restoration; and organisational collaboration. Each of the five strategic goals specifies ongoing objectives and the long-term vision for success in that area. Under each strategic goal, objectives describe what is to be accomplished over the next five years, and implementation tasks describe what agencies expect to do in order to accomplish that specific objective. To date, an estimated 67% of the first plan's 57 action items (encompassing over 100 separate elements) have been completed or are in progress.

Such a strategic document appears essential for Europe, effectively putting teeth onto the *European Strategy on Invasive Alien Species* (Council of Europe 2002). DAISIE has set a global precedent in the inventories of alien species and inspires others elsewhere in the world (Steiner 2009), fulfilled a pressing need within Europe (Fernández-Galiano 2009) and significantly raised awareness in European institutions (Miko 2009). While these are major milestones, we believe DAISIE and the *Handbook of Alien Species in Europe* is only the start: the start of the end to the fragmented legislative and regulatory requirements addressing invasive species (Miller et al. 2006). The start of the end to uncoordinated activities led by the different Directorates General (DG) of the European Union that do not appear to appreciate the cross-cutting nature of biological invasions (e.g., separate DGs for Agriculture, Environment, Health, Marine, Research, Transport etc.). The start of the end of piecemeal approaches to tackling invasive species across Europe that fail

to coordinate pre- and post-border actions (Hulme et al. 2008b). The start of the end of underfunding taxonomy, management efforts and basic research on invasive species. And finally, hopefully in the not too distant future, the start of the end of the progressive homogenisation of Europe's flora and fauna.

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