Protocol for Species Introductions. Modified from IUCN (1987) and amalgamating points from Panetta (1993), Hughes (1994) and Lonsdale (1994).

* Introductions should only be considered if clear and well-defined benefits to man or natural communities can be foreseen and demonstrated.

* Introductions should only be considered if no native species is suitable for the purpose for which the introduction is being made.

* Introductions should not be made into pristine natural or semi-natural habitats, reserves of any kind or their buffer zones and, in most cases, oceanic islands.

* The taxonomic identification of the proposed introduction needs to be confirmed.

Only if these first four conditions are met should further assessment proceed.

* Reports of weediness from other areas should be assessed. If the proposed introduction is a reported weed, in most cases this is grounds for rejection, unless overriding benefits can be demonstrated that outweigh likely costs. A full Environmental Impact Assessment is justified in such cases.

* Introductions should not be made until risks of weediness or invasion of surrounding areas have be assessed as far as possible, taking into account essential data on:

    (i) the autecology of the species (seed dispersal, reproductive ecology, factors limiting its distribution and abundance in its native habitat).

    (ii) conditions in the area of introduction (including the likely effects of rare climatic or other events such as flood, drought and fire).

    (iii) information on weediness form other areas and for closely related species.

    (iv) likelihood of interspecific hybridization with closely related native or other introduced species, and risk of contamination of native genepools through introgression or evolution of new and potentially aggressive polyploid species.

* Preliminary surveys for natural enemies/control methods should be carried out to assess potential for control and ensure eradication if needed.

* Introductions should be made initially in small, closely monitored field trials under quarantine conditions. Monitoring needs to include assessment of seed production and dispersal and natural regeneration into surrounding areas. Collection of seed by station workers or visitors from trials needs to be controlled by harvesting all seed before it ripens. When assessment is complete, trials need to be completely destroyed, including any soil seed bank that has developed.

* The case for a proposed introduction, including data on benefits and risks as outlined above, should then be put before the relvant national and/or state quarantine authorities for a final decsision. Costs should be borne by the intending importer.

proposed introductions and this in itself would undoubtedly lead to a dramatic reduction in the flow of new plant species around the globe. It would however go some way to ensuring that only plant species which are of proven use and benefit and which would result in net economic or ecological gain would be released.

PROBLEMS WITH ASSESSMENT OF BENEFITS AND RISKS

Assessment of benefits must first consider whether clear and well-defined benefits to man or natural communities can be foreseen and whether similar benefits or products could be derived from alternative native species. There would appear to be little justification for introductions of species that provide only basic products such as firewood, poles or green manure that are produced by a wide range of species. Over time, land use and production goals may change and species perceptions may be radically altered. A species that is highly preferred now may become obsolete and be perceived as a weed; for example, gorse (*Ulex europaeus*) has changed from a widely cultivated winter feed bush (Elly, 1846) to a pasture weed during the last century in the UK; correspondingly, a decline in demand for tannin has reduced the value of *Acacia mearnsii* in southern Africa. Market and technology changes may be hard to predict; a long-term perspective, although difficult to achieve, is required.

Assessment of risks relies on the ability to predict the outcome of an introduction through consideration of species characteristics, conditions (in the broadest sense) in the destination country, adequate dialogue between suppliers and seed recipients, and the use of accumulated information on invasive species from other areas and closely related species. The long-term behaviour of introduced species is complex and may be very difficult to predict (Panetta, 1993).

Prior to any assessment of risks and benefits, the identity of the plant must be confirmed. Although a well known weed elsewhere, a plant could be proposed for introduction under a synonym or erroneous name. Panetta (1993) cites a recent example of taxonomic confusion over the identity of *Acacia* introduced to Australia from Africa.

An "incubation" period (a few years to many decades) following introduction before species start to spread invasively, is a common phenomenon. Introduced species often only start to show invasive tendencies 50 or more years after introduction. *Acacia nilotica* in Queensland, Australia provides one example; introduced in the late 1890s, spread was not reported until the 1950s, and the species was declared a noxious weed in 1957 (Carter, 1994) and is currently the focus of a costly biocontrol programme. Other examples of time lags between introduction and spread are *Mimosa pigra* in Australia which was introduced c.1870-90 but only increased dramatically in abundance in the 1970s (Braithwaite *et al.*, 1989) and many pine species (Richardson *et al.*, 1994). In some cases this lag may be more perceived than real, reflecting a gradual initial spread which is only noticed much later as invasion progresses. In other cases, invasion may be triggered by unusual events such as storms, flooding, fire, or mis-management of livestock that create "transient invasion windows" (Richardson *et al.*, 1992), leading to massive regeneration or seed dispersal. In the case of *Acacia nilotica*, a series of years with above-average rainfall in the 1950s coupled with a switch from sheep to cattle grazing, appears to have precipitated dispersal and regeneration on a large scale (Carter, 1994). Many recently introduced species may be poised to spread given the "right" combination of conditions. This pattern of invasion is important given that most legislation and assessment of plant introductions relies on schedules that prohibit import of plants that are known weeds in other regions. Current invasive problems, although widely recognized to provide the most reliable predictor of risks (Panetta, 1993), may thus provide a poor guide to the future. Again, assessment needs to adopt a long-term perspective, examine long-term climatic cycles, the likely effects of grazing or fire and the possible outcomes of chance events. Assessment will always depend on thorough knowledge of the autecology of the species in question; very often this is not available at the time an introduction is contemplated but is only sought much later when invasion occurs and control measures are needed (*e.g.* Glendenning and Paulsen, 1955 for *Prosopis velutina*).

Species may spread widely from the initial point of introduction. A plant introduced anywhere in Africa, for example, can over time, quite readily spread itself into most habitats it can tolerate throughout the African continent. The assumption that an introduction may be a permanent addition to the flora should examine more distant localities and their conditions. Certain areas are particularly vulnerable to introductions and invasion. These include islands, including isolated biological systems, because their ecosystems offer refugia for species that are not aggressive competitors (Vitousek, 1988). Island floras are often rich in endemic species and on many islands costly battles are now being fought against invasive plants that threaten the last remnants of these floras (*e.g.* Strahm, 1990 in Mauritius). Protected areas and their buffer zones are another case deserving special protection. Small reserves are particularly susceptible to invasion, although easier to monitor and patrol against invasives (Janzen, 1983; 1987b) and new introductions must be considered inappropriate in such areas.

In addition to direct invasion, interspecific hybridization and the evolution of new taxa following introductions is of concern and its likelihood should also be assessed. For example, in South Africa: (i) formation of large hybrid swarms in *Lantana camara sensu lato* with subsequent ecological partitioning; (ii) trans-subgeneric natural hybridization between indigenous *Rubus rigidus* and exotic North American *Rubus cuneifolius* with subsequent swarming producing persistent new novelties (Stirton, pers. comm.[2]). Introductions may bring previously isolated species into artificial sympatry with either closely related native species, or other species that are also being introduced into cultivation. New hybrid taxa may present additional unpredictable threats of weediness or invasion, and introductions may "pollute" native species through hybridization and introgression (see review by Abbott, 1992 and Abbott and Milne, this volume). There are several examples of spontaneous hybridization resulting from plant introductions of all kinds including forestry activities: *e.g. Salix* in UK (White, 1994), *Leucaena* in Mexico (Hughes and Harris, 1995), *Acacia* in S.E. Asia (Sedgeley *et al.*, 1992), and *Prosopis* in South Africa (Poynton, 1990). In the case of *Salix* in the UK, there are numerous examples of loss of integrity of native species following hybridization with introduced species and cultivars (White, 1994) and the possibility of a single hybrid made up of all the species occurring in Britain has been mooted (Meikle, 1984). In the case of *Prosopis*, Poynton (1990) documents the introduction of six species to southern Africa from the New World. Spontaneous hybrids between *P. glandulosa* var. *torreyana* and both *P. velutina* and *P. chilensis* have been found to be extremely invasive, with

[2] Dr. C.H. Stirton, Director of Science and Horticulture, Royal Botanic Gardens, Kew, Richmond, Surrey, TW9 3AB, UK.

the ability to colonise a wider range of habitats than either of the parent species. Intercontinental movement of species in a large pantropical genus such as *Acacia* (as promoted by FAO/IBPGR, 1980) presents many opportunities for production of novel hybrids and pollution of native species.

Comparative studies of the determinants of spread and invasion across plant groups for which large numbers of species have been widely introduced such as those of Richardson *et al.* (1994) on *Pinus spp.*, offer insights into the likely outcome of future introductions. However, information about the behaviour and invasiveness of particular species from other areas appears to remain the best predictor currently available for immediate use (Panetta, 1993). The need for easy access to as much information about invasive species across the globe to guide assessment of new introductions provides sufficient justification alone for the establishment and development of a global database on weeds and invasive species as discussed by Frost *et al.* (this volume). Recent use of the electronic "Weeds of the World" server group for exchange of this type of information is indicative of the usefulness of this approach. Given the potential reliance that may be placed on information from such a database, this places a heavy onus on the database to be reliable and up to date; such a database will clearly require an international initiative to be successful.

Given these problems, accurate evaluation of risks may be extremely difficult and in some cases impossible, prior to an introduction. These difficulties place even more emphasis on thorough assessment of likely benefits which is usually easier; if large enough benefits can be demonstrated for a proposed introduction, including comparison with native alternatives, these are likely to outweigh any possible risks. By simply avoiding introductions that are not justified in terms of clear and substantial benefits, a considerable proportion of recent and current introductions would undoubtedly have been avoided.

MONITORING

Once assessment is complete and a species is approved as beneficial and unlikely to be invasive, introduction initially into small scale experimental trials that would permit eradication if cause for concern arose, is the recommended process (IUCN, 1987; Cronk and Fuller, 1995). However, such trials, which are normal practice in forestry introduction programmes, will provide only limited information on invasive tendencies. To be effective in controlling invasives, trials would need to be heavily protected, isolated and closely monitored for several years and in some cases decades; these conditions are rarely met in practice. Trial assessments rarely look at reproductive ecology or dispersal and regeneration; there are many cases where a few trees surplus to trial requirements are distributed to farmers; often on-farm testing of species is recommended; often trials remain in a neglected state long after assessment is complete providing a long-term source of possible invasives (Sheil, 1994); often seed is collected from trials by experimental station workers or visitors to plant in other areas or back in their gardens and farms. Thus, although trials provide scope for monitoring and control, and should be pursued with improved monitoring procedures, it is a fallacy that movement of introduced species can be reliably controlled at the stage of initial field testing of new tree species following current practice. Controlled introduction trials are not an adequate substitute for thorough prior assessment of benefits and risks. Botanic gardens with their huge reservoirs of potentially invasive species (Nelson, 1994), are similar in some ways to trials, although given their designed permanence, monitoring in this case needs to form an integral and on-going component of any environmentally responsible garden. Development of explicit guidelines for monitoring trials that address these inadequacies would help.

Alongside specific guidelines and procedures covering species introductions, Cronk and Fuller (1995) point out that education, awareness raising, legislation, information and record keeping can contribute to limit unwise introductions. Education of foresters and others working with trees is needed to raise awareness of the difference between native and exotic species, the importance of native trees, the dangers of exotics and the hazards associated with apparently harmless forestry activities such as testing new species in trials. Improved plant quarantine legislation is also an urgent priority with introduction of permit systems to authorize introductions. Accurate recording of introductions, invasive species, rates of spread, impact and ecological behaviour is essential in prevention and control of invasions.

CONCLUSIONS

Even if efforts to conserve and restore habitats succeed, the problem of non-native invasive plants is likely to get worse and to spread with time. It is inevitable that weeds will continue to be introduced, even under the protocols suggested here and however competent quarantine authorities may be. However, the general awareness of the damage caused by weeds, in particular to the natural environment, has engendered a will to prevent further import of potentially harmful species as far as possible and to bring the current unabated movement of plant species under closer scrutiny and control with strict application of protocols of the type outlined here. Given the lack of understanding of all the features of plants that confer weediness, any screening system is bound to remain imperfect; some harmless plants will be unnecessarily rejected while some will be accepted that later prove damaging. The consequences of the latter are far more serious; prevention is easier and much cheaper than cure.

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