Trade routes for commerce in plants or pathways for invasive species? The dualism of international commerce

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Summary The transport of commerce, at any geographic scale, is an on-going trial between costs and benefits. Trade is beneficial to the immediate trading partners, but the benefits for others may be elusive to identify. Furthermore, the fate of many immigrant species illustrates that far from benefits, there may be substantial costs to the public from the inadvertent escape of alien plant species through unregulated trade. All nations now have a legacy of alien species that have become invasive. The speed and volume of international trade combined with the highly idiosyncratic views among people as to what constitutes a desirable plant for import means that many more species will enter international trade in the future. Some of these will become invasive. As a result, national plant quarantine services and the recently established World Trade Organization will repeatedly face an old dilemma: what is the appropriate level of restriction to prevent the entry of potentially invasive plants but not unfairly restrict free trade? Although the poles in this debate (complete embargo on trade and no trade restrictions at all) are clear and will be avoided, the appropriate centric position is still poorly perceived. Some international guidelines appear prudent; there is the need to understand the expression of any species' attributes within a specific environmental context along with ample attention to the circumstances upon and soon after immigration. Each nation's application of these guidelines will require much experimentation and a willingness to erect a flexible quarantine framework that can implement improvements as we learn more about how plant entry actually leads to invasion compared with local extinction.

Keywords Biosecurity, international trade, pathways, quarantine, World Trade Organization.

INTRODUCTION

Trade has long been perceived as a necessity of human existence. However prolonged has been the age of hunting and gathering within living groups worldwide, I envision that the essence of the following statement was eventually uttered by humans in innumerable ancient languages (e.g. Assyrian, Latin, Mandan, Mayan, Prakrit) since the dawn of trade: 'Many of the commodities we desire and even some of our needs cannot be supplied close at hand. Our solution is to capitalise on our increasing skills and specialisations: we will trade the commodities that we harvest, gather or create in surplus for the commodities that we seek.' Begun at a modest scale in volume, the diversity of goods traded and the distances across which this trafficking occurred, trade has accelerated over thousands of years, developing into the vast arrays of trading webs that link almost all human (Tracy 1990, Smith 1991).

The perceived benefits of trade are so apparent as to need no attention here. Instead I deal with one aspect of the negative features of trade: specifically, the harmful consequences of the accidental or deliberate release of non-indigenous plants into a new range (Williamson 1996). Such negative and even disastrous consequences of alien organisms have long been realised as a threat from trade, and societies have attempted to deal with some of these releases for centuries with decidedly mixed results (Slack 1985, Westbrooks and Eplee 1999). The growing connectivity of nations through rapid and voluminous transportation and the recent erection of trading rules through the World Trade Organisation (WTO) have converged to potentially facilitate the spread of organisms to an unprecedented degree. Consequently, there is paramount need to understand both the risk of the unintended spread of plants and the steps needed at any governmental level to protect a region's environment and economy (National Research Council 2002).

A BRIEF HISTORY OF TRADE IN PLANTS

As implied above, plants have been objects of trade for millennia, although the record is often circumstantial. Egyptians were likely trading with their regional neighbours up and down the Nile watershed thousands of years ago. One apocryphal account reports Queen Hatshepsut importing incense trees from the Land of Punt (likely the region of modern Somalia) in 1500 BC (Hodge and Erlanson 1956). Irrefutable evidence of ancient trade in living plants – usually but not exclusively as seeds – is the spread of cereal agriculture far from the native ranges of wheat, barley and oats in Asia Minor across the Mediterranean Basin and throughout western Europe to the British Isles before 100 AD (Mack 2001 and references therein). In pre-1800 Europe the need for seed purity had been understood for more than a thousand years ('Thou

shalt not sow thy field with mingled seed.' Leviticus 19: 19) but was probably never achieved. As a result, the arrival of so many of the current ruderal species in Europe occurred so long ago that their foreign origins are cryptic (Kornas 1990).

Long distance trade, which probably reached its zenith in the ancient world with the transportation webs of the Romans (Warmington 1974), waxed and waned for a thousand years during the long decline of the Roman Empire and its successor states. But during this interval from approximately 400–1500 AD other networks trading in plants continued, obviously unaffected by the collapse of a Roman central authority that had once spanned much of Europe, northern Africa and the Middle East. Chinese traders linked much of China with Southeast Asia and India, and Malay traders extended this commerce to the west coast of Africa (Franck and Brownstone 1986). Native Americans developed trading routes across much of North America that trafficked in perishable seeds such as maize (Mack 1986). And Polynesian voyagers carried plants across immense expanses of the southern Pacific in voyages of colonisation that had the effect of introducing plants accidentally and deliberately into remote island groups, such as New Zealand and Hawai'i (Mack 1999 and references therein).

Amongst the main catalysts that triggered international trade as practised today was the apocalyptic fall of Constantinople in 1453 to the Ottoman Turks (Runciman 1965), which effectively severed some of the most important trade routes between Europe and Asia. With Constantinople and its trade routes controlled by unreliable trading partners, Europe feared the loss of sources for highly prised commodities, including such plant products as pepper, ginger, nutmeg, and cinnamon. The impetus for an alterative route by which these commodities could be obtained became an obsession and initiated exploration and subsequent colonisation by European powers for the next 400 years. The trade routes eventually developed through the explorations of da Gama, Columbus, and Magellan, were motivated to various degrees by the need to acquire plants and plant products. Routes across the Indian Ocean to China and Japan, across the Atlantic to the Americas, and the incredible regular voyages from Mexico to the Philippines had been established by 1700 (Schurz 1959). But the movement of trade along these routes was expensive (even if spectacularly lucrative), did not meet the demand, and was fraught with peril. An alternative was needed. What safer way to ensure a reliable source of these commodities than to introduce these plants closer to home or at least within secure foreign colonies? Consequently, the trade for cacao, indigo, rice, and sugar eventually developed into the acquisition and introduction of the source plants for these important commodities into many new ranges (cacao to West Africa, indigo and rice to southern North America, and sugarcane throughout the tropics and sub-tropics (Viola and Margolis 1991).

The industry, soaring ambition and sheer audacity of those engaged in introducing species to new ranges around the world from 1500 to 1900 rival the vaunted reputations of the entrepreneurs of Europe and North America's Gilded Age, or even our current generation of international business moguls. By 1800, hundreds of species had been transported to new ranges, and many more were dispersed with the development of steamships and railroads (Campbell-Culver 2001, Mack 1991). Not only were crops being introduced, but so also were plants for use as seasonings, forage, medicine, soil stabilisation, ritual and ornamentation. Even colonies faced with the dire necessity of establishing crops and forage species still included a few plants for aesthetic uses amongst the earliest shopping lists from their homeland (Mack 2003). Such deliberate introductions remain by far and away the largest list of species carried to new ranges (Mack and Erneberg 2002).

PROBLEM ORGANISMS IN TRADE: THE DEVELOPMENT OF QUARANTINE

The introduction of organisms from afar was not without its risks, even if these risks did not initially loom high on the list of concerns among trading nations. For all the benefits of foreign trade, participants to varying degrees and with varying speed came to realise that trade could also bring disaster in the form of human disease. Medieval Europe paid an horrific price in human suffering for ignorance about the parasitic basis for disease and the pathways by which these parasites were being spread. The era's only effective tools for combating these species were combinations of careful observation and inductive reasoning. Correlation, then and now, can in the right hands be a useful, if imperfect, guide to the truth. And the correspondence of ship arrivals from foreign ports with new disease outbreaks (along with news from the passengers of an epidemic in their port of departure!) would have rapidly led to the opinion that one way to prevent these outbreaks was to screen ships and their contents before disembarkation, and in some cases to forbid ships from landing at all (Markel 1997 and Slack 1985).

Quarantine measures maintained by governmental authority at ports, borders and frontiers for preventing the entry of unwanted foreign organisms began as prevention borne out of the catastrophic experience with the totally unrestricted movement of humans and their cargoes. The origins of quarantine predate

medieval experience and have been independently formulated in different cultures. Rudiments are seen in the Biblical treatment of lepers (Leviticus 13: 45-46), a law enacted by Emperor Justinian in Constantinople in 549 AD forcing the isolation of sailors and other travellers from regions where the plague was known to occur, and similar edicts in 7th century China (Markel 1997 and references therein). Sustained enactment of quarantine, again in response to the plague, began in 13th century Italy, and these practices were adopted across Europe as the plague spread from Venice to the rest of Europe and Britain (Slack 1985). Unfortunately, early quarantine practices did not specifically target organisms other than humans. But the lessons of shipboard isolation and the need to destroy infected cargo would prove useful later as alien species, other than agents of human disease, attracted attention.

Even as quarantine regulations were extended through the 19th and 20th centuries to deal with microbial parasites and insects that attack crops and domestic animals, specific prohibitions against the entry of harmful alien plants were almost totally restricted to plants that harbour insect and microbial pests of plants (Fulling 1943). The US was especially tardy in identifying and combating the entry of invasive and otherwise harmful alien plants. Paradoxically, while a few plants had long been viewed as injurious to American agriculture (e.g. thistles, *Berberis vulgaris* L., parasitic plants and *Salsola kali* L.), State laws only prohibited their inter-state movement; no Federal laws operated at the nation's borders (Fulling 1943). Plant species that were banned from importation were eventually listed in the Federal Plant Quarantine Act of 1912 and, beginning in 1919, under numbered quarantine supplements promulgated under the 1912 law. Species under these directives were banned because they were deemed vectors of plant pests, not because they were seen as plant pests themselves (Weber 1930). Despite ignoring the flood of alien and potentially invasive species still arriving in the US as seed contaminants and as deliberate introductions (Mack 1991 and Mack and Erneberg 2002 and references therein), the directive did restrict a few species that were potentially harmful in their own right (e.g. the haploxylon subgenus of *Pinus*, *Ribes* spp., and the grasses *Coix lachyrma-jobi* L., *Pennisetum purpureum* Schumach, *Sorghum halapense* (L.) Pers. and *Sorghum sudanese* (Piper) Stapf (Weber 1930). Most useful may have been the ban on all alien bamboos, thereby protecting the US from the spread of temperate and even frost-tolerant bamboos from eastern Asia, until the ban lapsed into lax enforcement (Mack 2003). The 1917 Quarantine No. 37, which was intended to place sweeping prohibitions on nursery stock (vegetative plants and seeds), could have provided broad, if somewhat unfocused, protection. With some justification, the horticultural industry in the US vigorously attacked this directive, and its full intent was never realised (Weber 1930).

Through political resistance or governmental neglect, or both, the necessity of prohibiting the entry of some alien species from importation in the US because of their invasive potential was not recognised in law until enactment of the Federal Seed Act of 1939 (US Congress 1939). For the first time, Federal authorities in the US were charged with inspecting and rejecting seed lots contaminated with the seeds of some alien species. Through its additions and amendments the law is not designed as a total ban, but sets limits on seed contamination under which seed imports can still proceed. The more extensive Federal Noxious Weed Act of 1974 and its additions now ban the accidental or deliberate importation of about 100 alien species in the US (Westbrooks and Eplee 1999). Unfortunately, some of the species in this list are already in the US, although a ban on further imports reduces the risk of importing novel (and potentially aggressive) genotypes (Saltonstall 2002).

Few nations, and the US is not among them, provide comprehensive protection against the entry of potentially invasive plant species. New Zealand's Hazardous Substances and New Organisms Act of 1996 is a model of national protection. For any species not already introduced into New Zealand, a rigorous application process must be completed that involves an extensive review of the species' biology and immigration history elsewhere, including whether it has escaped cultivation and become naturalised (Anon. 2001). Australia, both at the Federal and State levels, has adopted protocols that provide similar assessment (Pheloung 1999). Limitations within these risk assessment systems include the potential lack of sufficient knowledge of a species' importation history (e.g. no track record of behaviour in a new range) as well as no knowledge of its ecology. Little more than the species' description may be available along with some information about its native range and presumed environmental tolerances (Randall 2002). These are serious shortcomings in current risk assessment systems. But these problems may be rendered moot, or at least subject to increased scrutiny, by the sweeping powers of the WTO to encourage free trade, including the international trade in living plants.

WORLD TRADE ORGANIZATION AND THE MOVEMENT OF PLANTS

The need has long been recognised for international cooperation on standards by which trading nations would protect their domestic plant resources from

any detrimental consequences arising from the importation of alien plants. As a result, phytosanitary principles were codified in the International Plant Protection Convention (IPPC), beginning in 1951 and its periodic revisions (FAO 2000). Although the IPPC has emphasised protection against plants that harbour pests of plants, its provisions also include protocols for evaluating alien plants themselves as risks in a new range (AQIS 1998).

The transport of plants has been discussed within broad international negotiations to regulate and facilitate trade. Repeated rounds of trade talks since 1947 produced by the early 1990s sweeping international agreements on many aspects of trade, including the protocols that would govern the import/export of living plants (FAO 2000). These protocols involve voluminous trade policies under the aegis of the WTO; only a small part of these binding agreements, the SPS Agreement, concern us here.

The WTO 1994 Agreement on the Application of Sanitary and Phytosanitary (SPS) Measures obligates member nations to create or modify a national quarantine system that prevents the entry, establishment and spread of harmful alien species, including plants. The six key points of the SPS Agreement quoted below from Shine *et al*. (2000) spell out in broad terms the criteria by which any nation can protect itself from the importation of harmful plants. The Agreement promotes or requires:

1. 'international standards as a basis for SPS measures;
2. risk assessment based on scientific principles and evidence;
3. consistency in the application of appropriate levels of protection;
4. least restrictive trade alternatives;
5. acceptance of equivalent alternatives; and
6. transparency through notification of trade measures'.

As with so many binding agreements, 'the devil is in the details' and in particular how these principles are interpreted and applied from one nation to another. Differences in interpretation were foreseen by the authors of the WTO, and a mechanism was created for adjudicating bi-national disputes with binding arbitration (FAO 2000). I discuss briefly here some of the knotty issues that have already been raised in application of these key points with respect to the international movement of plants.

Points (3) and (6) seem reasonable or at least not as subject to different interpretations as other points. Point (4) illustrates the *raison d'etre* for the WTO: facilitate and enhance free trade among member nations and create a framework in which an agreement such as the SPS does not serve as a hidden trade barrier. These points are outside my discussion.

Points (1) and (2) are so intertwined that they are considered here together. The need for international standards appears to be an acceptable current criterion, and the IPPC standards form the basis under the SPS Agreement (Shine *et al*. 2000). A bi-national dispute could arise here from the criteria that the IPPC employs and their clarity and specificity. Although the IPPC evaluation system includes extensive procedures, listed in flow-diagram fashion, the lack of specific information on a species under scrutiny often forces an expert judgment or information on a congener to tip the scales for or against importation (AQIS 1998). Obviously, the skill of the experts could be questioned, especially since IPPC allows stakeholders (i.e. the importer) to nominate technical experts (AQIS 1998). Given the vast array of plant species that have no importation history or for which there is little or no ecological information, an expert judgment system can be stretched quickly to the limits of current knowledge. In addition, reliance on information about a comparable species (e.g. same genus, same life history features), as allowed under IPPC guidelines, is an imperfect guide. For instance, the number of examples in which congeners have become invasive, such as in the genera *Centaurea*, *Rumex*, and *Cuscuta*, is dwarfed by the cases of a single invasive species within a genus with no other invasive members (e.g. *Eichhornia crassipes* (Mart.) Solms*, Hypercum perforatum* L., *Hydrilla verticillata* (L.f.) Royle and *Sapium sebiferum* (L.) Roxb.).

Reliance on related species touches on one of the more contentious and unresolved issues about predicting the identity of future invasive species amongst a nation's imports: risk assessment based on scientific evidence and in particular evidence based on the traits, features and ecology of alien species. Seeking generalities about the traits that pre-dispose a species to become invasive in a new range is logical and is an outgrowth of biologists' long-term search for commonality in nature from a vast array of biological information. Distilling and applying that information to predictions about a species' ability to invade has been challenging and often seems more retrospective than truly predictive (Daehler and Carino 2000). More success in meeting the standard of risk assessment based on scientific evidence will likely result from a synthesis of species' traits, their environmental context (detailed comparisons of native and alien ranges), and especially knowledge of the degree to which stochastic events (e.g. weather at the time of entry, size and genetic makeup of the founder population) dictate whether an immigrant species will survive (Mack

2000). Basically, the prediction of which species will become invasive in any new range is in its infancy but appears nonetheless tractable (National Research Council 2002).

Finally, point (5) – the acceptance of equivalent alternatives in mitigating or reducing the risk of releasing a harmful plant into a new range – has already served as a lightning rod for debate. Simply stated, bi-national agreements on point (5) turn on whether the quarantine service of one nation (the importer) will accept the standards that an exporting nation has applied in clearing a plant species (either accidentally or deliberately transported) for export. Even a cursory examination of quarantine services among nations reveals differences that vary with the plant commodity and the care exercised to inspect general cargo for accidental plant transfer. Here as elsewhere in application of the SPS Agreement, there is ample opportunity for the non-harmonious juxtaposition of two WTO principles: each nation retains its right to protect its domestic resources from the introduction of alien pests. But member nations should also seek solutions that facilitate free trade. Melding these two potentially opposite goals for the international trade in plants will require a much larger input of careful scientific observation, experimentation, synthesis, and risk assessment than has been undertaken so far (National Research Council 2002).

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