Eradication or control? Combating plants through a lump sum payment or on the instalment plan

Richard N. Mack and Sara K. Foster
School of Biological Sciences, Washington State University, Pullman, WA, United States of America

Summary The advantage of eradicating, compared with controlling potentially invasive plants seems clear: the pestiferous species is eliminated and additional resources (other than to detect its re-entry) will not be needed. The counter argument (or lament) is that eradication, except for rare cases in which the alien species occurs in small, identifiable foci, is either financially or logistically impossible, or both. Arguments against eradication as a goal usually point to the supposedly more practical and attainable goal of control, whereby the alien species is prevented from or slowed in occupying new range or even reduced in area and extent over time. We liken this common distinction between eradication and control to paying one lump sum for a service compared with paying for it on the instalment plan. But is control really cost effective and should eradication be considered only for recent immigrants at their beachhead(s)? We contend that the answer to both questions is 'No.' Control is often a poor bargain, as it requires the indefinite commitment of public funds. But the public seldom makes long-term funding commitments. If the control effort is reduced or abandoned for whatever reason, all the accumulative effort applied earlier may be rapidly undone once the invasive species resumes its spread. Eradication not only precludes that consequence, but the cost of preventing the species' reintroduction is usually a small fraction of any control effort. Furthermore, the record of plant eradication in the United States reveals that eradication can be achieved if several rules are scrupulously followed, including the initial destruction of nascent foci and the routine survey of treated areas until no additional plants are detected. Eradication should be considered as a practical option in combating potentially invasive plants in many more cases.

Keywords *Berberis vulgaris*, control, eradication, *Hydrilla* spp., nascent foci.

INTRODUCTION

We begin our argument for the eradication of potentially invasive plants with a cautionary tale. Although it draws on a case of an invasive species, it is not a plant, and while the case for damage is unequivocal, the damage was not to a habitat or a natural community, or even a crop. We choose to illustrate with the post-1990 resurgence of tuberculosis in the US, the high price extracted from society by first failing to eradicate an invasive species and then relaxing the minimum level of control.

Tuberculosis (TB) is an all too well known, highly contagious disease caused by *Mycobacterium tuberculosis*. Its symptoms need no elaboration here: respiratory infection can rapidly develop into chronic respiratory distress, weight loss, and in extreme cases, death. Fortunately, there is still a battery of antibiotics that can successfully combat the bacterium in the host and largely rid him/her from any symptoms, although whether total elimination of *M. tuberculosis* bacilli in the host is achieved is equivocal. In the US, as in much of the developed world, TB had become largely a disease of the past by the 1960s – joining whooping cough, scarlet fever and diphtheria as diseases rarely seen in the general public. But TB had never been eradicated in the US; there had always been residual population(s) of *M. tuberculosis* in humans to which new genotypes were added through ineffective screening of foreign visitors and immigrants (Munsiff *et al.* 2003, Schneider and Castro 2003). Worse still, the low incidence of the disease had lulled public authorities into considering that the pathogen was on its heels and that scarce public funds for routine screening and isolation of TB patients could be better spent elsewhere.

The fallacy of failing to maintain an active campaign to identify and treat all TB carriers became all too apparent when TB roared back in some US cities in the early 1990s. New York City became the scene for a conspicuous epidemic beginning in about 1992 (Munsiff *et al.* 2003, Schneider and Castro 2003). New York had all the elements to maximise spread: high human density meant high opportunity for the spread of the bacterium from one host to the next, laxness by local officials in anticipating spread and maintaining isolation facilities, pockets of high-risk hosts in the city's homeless, and the potential for new genotypes to arrive with an influx of immigrants largely from poorer nations.

For one of us (RNM) this epidemic had a personal dimension. My nephew, Ted Lehmann, was one of its victims. As a healthy 27 year old student, he would have appeared at first to have a low risk of infection. But somewhere as he made his way through New York

City in 1996 – whether on the subway, in a crowded room, or some other close encounter, he came within the transmission distance for *M. tuberculosis* from an infected person. Once diagnosed, he began a strict nine month regimen of antibiotics and is today without symptoms. But he may remain a latent carrier. As a result, he cannot give blood and must be diligent about his general health. Even before Ted contracted TB, public officials belatedly realised the seriousness of the outbreak and huge amounts of money were poured into screening, isolation and treatment programs throughout the 1990s. These programs continue (Li *et al.* 2003). But the cost of this belated campaign dwarfs the amount that would have been needed to maintain a diligent detection and treatment program. What remains unclear is whether this scenario will again be played out decades from now or whether the lessons from the 1990s have been ingrained into public consciousness.

Although tuberculosis and New York City may seem far removed from combating invasive alien plants in Australia and elsewhere, the causes of this resurgence provide stark lessons that apply to all species capable of arriving and proliferating in a new range that lacks strong biotic or physical constraints. As we contend below, the reduction of an invasive alien species (IAS) by whatever means to a low level of occurrence should not be a signal to relax the destruction effort. It should trigger the opposite response: total destruction, i.e. local extinction in the new range is at hand and can be achieved with a sustained eradication campaign. To do otherwise is to invite a re-playing of the original spread of the species with all its attendant detrimental consequences.

CONTROL OR ERADICATION?

Arguments for the control of invasive plants compared with their eradication take many forms, and many are often difficult to quantify, even in economic terms. One of the persistent deficiencies in combating invasive species is a lack of cost:benefit analysis at any level (Perrings *et al.* 2000). Not only does the harm caused by an IAS justify any action against it, but this harm also justifies tabulation of the return on the investment in different tactics (treatments with mechanical, chemical, biological controls) and strategies (combating the largest infestations first or attack the nascent foci, and if so, in what order).

Arguments advanced for control, including so-called maintenance control, usually include the following elements. The number of invasive or at least harmful alien species in many areas is large, and funds to deal with these species almost never equal the cost of their control, much less their eradication. The damage caused by many of these species is at best reduced to a tolerable level (Schardt 1997). For instance, the emphasis in agriculture is to control the pest(s) such that their density is so low that a commercially viable crop can still be harvested. For weeds in a crop, total elimination is usually not deemed necessary. Furthermore, it is argued that control is the more rational solution compared with eradication because achieving eradication, i.e., local extinction of the IAS, becomes progressively more expensive and difficult as the pest becomes rarer in the landscape (Denne 1988). Finding and destroying the last few individuals may involve an inordinate cost compared to the ease and cheapness of destroying the species when it was abundant. Furthermore, the economic cost of destroying the species once it becomes rare means that the public may see little apparent gain from the price for eliminating the few surviving populations. This notion of reduction to an acceptable or at least tolerable risk or cost is widespread in combating other ‘pollutants’, such as radioactive waste, chemical pollutants in water and soil and air pollutants.

The counter argument for eradication begins with the realisation that IAS are unlike chemical pollutants: they have the potential, even if reduced to very low levels of detection, to reproduce and expand their numbers rapidly. Heavy metals and other chemical pollutants present challenges to their containment, but they are usually more readily sequestered than an IAS, e.g. erecting a quarantine zone around the known populations of the IAS. Escape of trace amounts of a heavy metal or even a radioactive material is to be avoided but still does not hold the consequences of the escape of a few organisms that can establish a new focus far removed from the original area(s) of infection. Furthermore, simply controlling an IAS at some level requires that public funds will be available indefinitely to maintain the control effort. But as the resurgence of TB in the US so tragically illustrates, public officials are beset with myriad demands on the public’s money. It is easy to adopt an ‘out of sight, out of mind’ attitude: an issue that has not been a problem for decades, could easily lapse in the public consciousness to become a problem erroneously perceived as solved.

Another commonly stated argument against eradication of IAS plants is that while it may be possible at the outset of a species’ residence in a new range, if the area occupied is >1000 ha, the likelihood of eradication drops precipitously (Rejmánek and Pitcairn 2002). Using the following examples, we contend eradication is a practical and even the best solution for combating a far larger array of plant invasions than is generally recognised. Our argument is based on past and recent on-going examples and is not restricted by taxon or geographic region. Although oceanic islands present an intrinsic advantage in eradication – their isolation presents the opportunity to minimise, if not prohibit re-entry – eradications have been successful on continents (Mack and Lonsdale 2002). And most important, eradications can be achieved against a highly dispersible IAS and across huge areas with diverse habitats.

We employ two examples. The first is the failure to eradicate a now invasive aquatic vascular plant in Florida (*Hydrilla verticillata* (L.f.) Royle). As counterpoint we provide a second example – largely erased from the institutional memory of federal agencies in the United States of America (USA) – the virtual eradication of the European barberry (*Berberis vulgaris* L.) in much of the USA in the 20th century. This second example illustrates that if public will is focused, eradication can be achieved even against a widespread, abundant plant invader.

COMBATING *HYDRILLA VERTICILLATA* IN FLORIDA (USA): A SISYPHEAN TALE

The introduction, spread and treatment of *Hydrilla verticillata* (hydrilla) in Florida (USA) in the past quarter century holds parallels to public attitudes about TB before 1990. *Hydrilla* spp. were deliberately introduced into the USA in the aquarium trade, and *H. verticillata* soon appeared in freshwater systems through repeated accidental introductions and probably through deliberate introductions that were perpetrated as boons to recreational fishing (Schardt 1997). Hydrilla is a submerged perennial monocot, which can persist and spread through seeds, tubers, stolons, turions and vegetative fragments. Dispersal by seeds is minimal; stolons and tubers can disperse locally, and tubers are a resilient over-wintering structure. Dispersal is mainly by turions and especially by simple fragmentation of vegetative shoots (Parsons and Cuthbertson 1992).

Hydrilla started to draw the attention of resource managers in Florida in the late 1960s. At that time the species was prevalent only in some lakes and eradication would have been possible. A prolonged research period ensued in the 1970s in which knowledge about the plant's basic biology in Florida and potential effects on native biota was assembled as well as realisation that its multiple forms of vegetative propagation would make early treatment imperative (Schardt 1997, and references therein). Unfortunately, public response became a mixture of routine apathy toward an alien that was not yet a problem and the lack of adequate funds to combat a new threat when so many others already crowded the state budget. In addition, some believed that the spread of hydrilla was fortuitous. This segment of society contended that hydrilla provided a new food source for waterfowl and initially improved water clarity, thereby improving recreational fishing (Schardt 1997)! Consequently, the opportunity for early eradication was lost, and even the control effort was fitful.

By the mid-1990s the decidedly negative effects of hydrilla on freshwater systems were apparent, but the wax-and-wane of funding to combat it continued. As a result of this indecisive approach, the area occupied by hydrilla declined sharply in years when funding increased, only to increase sharply once funds (for whatever reason) were withdrawn: plots of area occupied (a correlate of the abundance of hydrilla) and dollars annually expended take the form of Lotka-Volterra coupled oscillations between predator and prey (Doren and Center 2001). This inconsistency to control, much less eradicate, the pest has meant that the total area occupied by *H. verticillata* in Florida continues to increase (Figure 1).

More poignantly, each rebound of hydrilla during periods of low funding for its control undercuts the effects of the earlier funding – the toil of Sisyphus re-enacted in terms of environmental protection. The public might take a more determined view about the need for eradication (or at least the attempt for eradication), if they were fully aware of how much money has been spent in the past 25 years (it will soon exceed US$100 million), compared with the cost of an all-out eradication and subsequent monitoring campaign upon the first appearance of hydrilla in Florida.

THE ERADICATION CAMPAIGN AGAINST *BERBERIS VULGARIS* IN THE USA

Berberis vulgaris L. (European or common barberry) is the alternate host for the stem rust (*Puccinia graminis f.* sp. *Tritici*) of wheat. It was introduced into North America in the early 17th century as a source of fruit for preserves, a living fence and as an ornamental (Mack 2003). Long before direct evidence of the microbial basis for stem rust, the coincidence of the disease in districts that also had barberry had been recognised (Fulling 1943). Unfortunately, this astute observation was hotly contested until the firm establishment that some fungi do indeed cause disease, such as stem rust, and that *B. vulgaris* is the rust's obligate alternate host. But by the time this crucial observation had been publicly accepted, barberry had been planted across most of the northern USA. By the early 20th century, losses of wheat to stem rust had reached epidemic proportions, which exacerbated the shortfalls for wheat production in Europe during World War I.

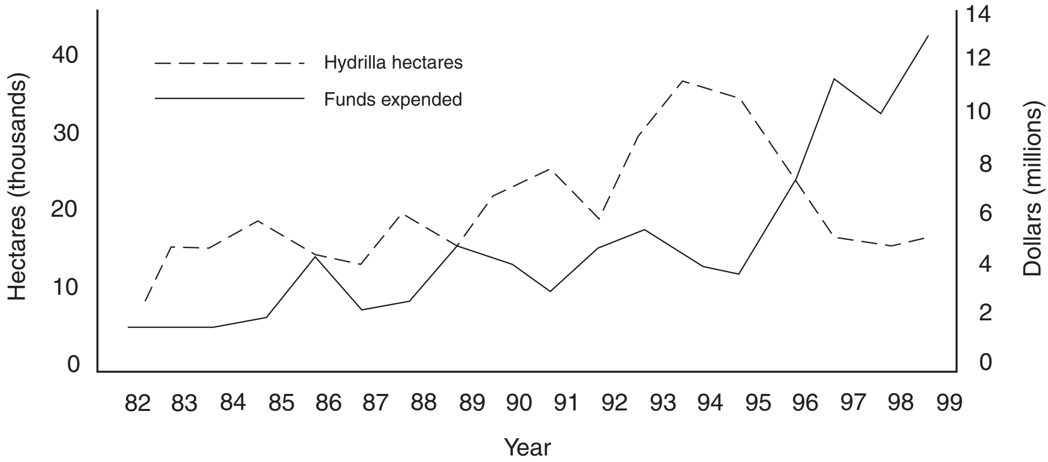

Figure 1. Hydrilla hectares versus funding in Florida public waters, 1982–1999. The control of *Hydrilla verticillata* in Florida, USA, has been sporadic and each pause in the funding for control has brought about expansion of its range (redrawn from Doren and Center 2001).

From 1919 until the 1930s, the United States Department of Agriculture (USDA) supervised a massive campaign to eradicate this alternate host, by poisoning or removing all *B. vulgaris* within the wheat-growing states from Pennsylvania to Montana (Figure 2). This public campaign was immense in all aspects: thousands of people were involved, including many high school students, who 'foot-scouted' the countryside searching for barberries. The results were spectacularly successful: millions of plants were destroyed and more important the incidence of stem rust in wheat plummeted (Stakman 1919, Freeman and Melander 1924, Hutton 1927).

The eradication campaign for barberry moved west during World War II. Wheat-growing districts in the Far West (Oregon and Washington) had not been part of the earlier campaign, even though barberry had been widely introduced there from the late 19th century onward. Whitman County, Washington was typical of these areas – as much as 1/3 of the county's 5592 km^2 continues to be sown to wheat (National Agricultural Statistical Services 2002), far too much to leave susceptible to stem rust infection. From 1944 until 1978, the USDA employed techniques perfected earlier in the mid-continent to destroy all the barberry. Diligent searches were initially conducted around *every* building in the county on the premise that barberry was most likely to have been initially introduced near sites of human habitation and then could have been carried by birds elsewhere. If barberry was detected near a building, it was destroyed, and then the search expanded from the site for a radius of one mile. All barberry, i.e. seedlings as well as adults, were destroyed in these wide circles. These search-and-destroy missions often occurred in terrain with high relief and dense vegetation. The campaign deliberately re-examined these same large areas for multiple years after a barberry was first detected, to ensure that any plants that had been initially overlooked were eventually detected. Finding previously undetected plants extended the period of surveillance. Only after no new plants had been detected for three successive years was a property declared barberry-free. This was a laudable strategy, but federal funding was withdrawn before all properties could be considered free of barberry, based on this three-year rule. Nevertheless, 49,313 plants had been destroyed in Whitman County by 1978 (Busdicker 1945, Shepard 1966, Campbell and Long 2001).

In 2002–2003 we re-surveyed 100 properties that had not been declared barberry-free in 1978, reasoning that if barberry remained it would most likely occur on these sites. Amongst all these properties, we found only nine barberry plants. The oldest plant was approximately 22 years old, suggesting that it was a seedling at the time the eradication program ended in 1978. Although the campaign in Whitman County did not achieve eradication in a strict sense – some plants remain – the results achieved were far beyond simply 'control'. The species was reduced below an intense level of detection, and no new seedlings were found in 2002–2003.

An optimistic view of the status of barberry in the USA today is that it resides only in small, isolated populations that present no danger. In the alternative

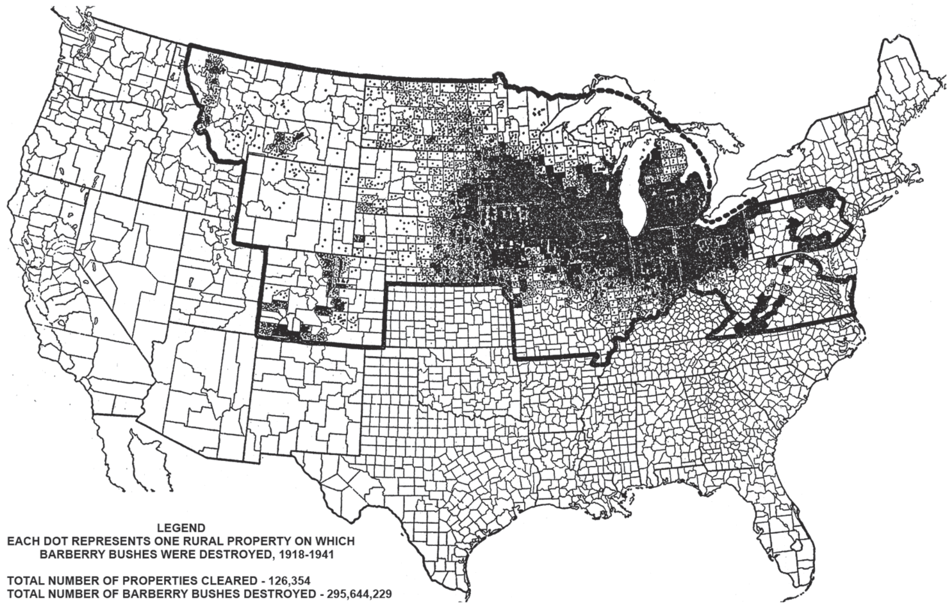

Figure 2. States cooperating in the barberry eradication program for the control of stem rust, 1918–1941. *Berberis vulgaris* was eliminated from an enormous number of properties (converging black dots) across much of the northern USA in the first half of the 20th century (modified from Fulling 1943).

view, these populations are functionally equivalent to scattered nascent foci that have the potential not only to spread locally but also contribute to the establishment of distant foci through bird-dispersal (Moody and Mack 1988). What is needed now is renewal of the barberry eradication campaign to eliminate the few plants that escaped earlier detection in the mid-continent USA and the Far West. The lapse in public commitment to such action is worryingly reminiscent of the failure to eradicate *M. tuberculosis* and prevent its re-entry into the USA.

CONCLUSIONS: FIVE TENETS FOR ERADICATION

The tenets for eradication derived from the lessons with barberry and other IAS are remarkably straightforward (Mack and Lonsdale 2002).

1. Early detection is essential, whether for the first entry of an alien species in a new range or the detection of widely spaced populations of a long-term resident IAS.
2. A course of action, including the tactics (tools) and the strategy (order of attack in terms of the species' distribution) must be swiftly decided.
3. All plants must be destroyed, regardless of age and location, beginning with the nascent foci and then proceeding to the major areas of infestation.
4. Long-term searches for overlooked plants or new recruits must continue for a prolonged period. Criteria as to when the search can be prudently suspended should be based on the frequency of new detections and the biology of the IAS (e.g. duration of seed bank, mode of dispersal, age at first reproduction).
5. If re-introduction can occur (e.g. as seed contaminants in a commodity that is still imported), the search for the IAS continues as part of a comprehensive early detection system for all new immigrants.

Our thesis is that too often these tenets have not been practised or practised tentatively or sporadically. The result is little better than if no containment effort had been exerted at all. Admittedly, much of the solution is convincing the public and policy makers that IAS are serious chronic hazards that exact a heavy toll from all and that this environmental and economic toll can be reversed with the determined and early application of an eradication campaign. Once the public realises the personal savings from this course of action, the demand will be resounding.

REFERENCES

Busdicker, H.B. (1945). Washington annual report, barberry eradication project. (USDA, Pullman, WA, USA).

Campbell, C.L. and Long, D.L. (2001). The campaign to eradicate the common barberry in the United States. *In* 'Stem rust of wheat: from ancient enemy to modern foe', ed. P.D. Peterson, pp. 16-43. (APS Press, St. Paul, USA).

Denne, T. (1988). Economics of Nassella Tussock (*Nassella trichotoma*) control in New Zealand. *Agriculture, Ecosystems and Environment* 20, 259-78.

Doren, R.F. and Center, T.D. (2001). 'Weeds won't wait! A report to the South Florida Ecosystem Restoration Task Force and Working Group. Part 1. An assessment of invasive exotic plants in Florida.' (South Florida Ecosystem Restoration Task Force, Miami, USA).

Freeman, E.M. and Melander, L.W. (1924). Simultaneous surveys for stem rust: A method of locating the sources of inoculum. *Phytopathology* 14, 359-62.

Fulling, E.H. (1943). Plant life and the law of man. IV. Barberry, currant and gooseberry, and cedar control. *Botanical Review* 9, 483-591.

Hutton, L. (1927). Barberry eradication reducing stem rust losses in wide area. 'Yearbook of Department of Agriculture', pp. 114-8. (Government Printing Office, Washington, DC.).

Li, J.H., Driver, C.H., Munsiff, S.S., Yip, R. and Fujiwara, P.I. (2003). Differential decline in tuberculosis incidence among US- and non US-born persons in New York City. *International Journal of Tuberculosis and Lung Disease* 7, 451-57.

Mack, R.N. (2003). Plant naturalizations and invasions in the eastern United States: 1634–1860. *Annals of the Missouri Botanical Garden* 90, 77-90.

Mack, R.N. and Lonsdale, W.M. (2002). Eradicating invasive plants: Hard-won lessons for islands. *In* 'Turning the tide: the eradication of invasive species', eds C.R. Veitch and M.N. Clout, pp. 164-72. (IUCN SSC Invasive Species Specialist Group, Gland, Switzerland, and Cambridge, UK).

Moody, M.E. and Mack, R.N. (1988). Controlling the spread of plant invasions: The importance of nascent foci. *Journal of Applied Ecology* 25, 1009-21.

Munsiff, S.S., Nivin, B., Sacajiu, G., Mathema, B., Bifani, P. and Kreiswirth, B.N. (2003). Persistence of a highly resistant strain of tuberculosis in New York City during 1990–1999. *Journal of Infectious Diseases* 188, 356-63.

National Agricultural Statistics Service. (2002). (http://www.nass.usda.gov:81/ipedb). (Agricultural Statistics Database, US Department of Agriculture website).

Parsons, W.T. and Cuthbertson, E.G. (1992). 'Noxious weeds of Australia.' (Inkata Press, Melbourne).

Perrings, C., Williamson, M. and Dalmazzone, S. (eds) (2000). 'The economics of biological invasions.' (Edward Elgar, Cheltenham, UK).

Rejmánek, M. and Pitcairn, M.J. (2002). When is eradication of exotic pest plants a realistic goal? *In* 'Turning the tide: the eradication of invasive species', eds C.R. Veitch and M.N. Clout, pp. 249-53. (IUCN SSC Invasive Species Specialist Group, Gland, Switzerland, and Cambridge, UK).

Schneider, E. and Castro, K.G. (2003). Tuberculosis trends in the United States, 1992–2001. *Tuberculosis* 83 (1-3), 21-9.

Shepard, D.R. (1966). 'Barberry eradication manual. Plant Pest Control Division regulatory manual.' (Plant Pest Control Division, Hyattsville, Maryland, USA).

Schardt, J.D. (1997). Maintenance control. *In* 'Strangers in paradise: impact and management of nonindigenous species in Florida', eds D. Simberloff, DC. Schmitz and T.C. Brown, pp. 229-43. (Island Press, Washington, DC.).

Stakman, E.C. (1919). The black stem rust and the barberry. Yearbook of the Department of Agriculture, pp. 75-100. (Government Printing Office, Washington, DC.).