Invasive Weeds on Range and Farmlands—Problems, Causes, and Solutions

An interview with Richard Mack

Richard N. Mack is a professor in the School of Biological Sciences at Washington State University. For approximately the last 30 years his research has been largely devoted to the ecology of invasive species. Much of his research has dealt with the aggressive invader, *Bromus tectorum* (cheatgrass or downy brome) in the Intermountain West of the United States. He has also investigated plant invasions in Hawaii, the southeastern United States, and China. He is particularly interested in the population biology (including the immigration, demography, competition, and ecological genetics) of plant invaders and their environmental effects. He has framed much of his research with the goal of addressing applied aspects of combating invasive species, including the prediction of future invasive species and their early detection and eradication.

Richard Mack.

He served as chair of the Department of Botany at Washington State University, 1986–1999. He served as chair from 1999–2001 for the National Research Council's Committee for Predicting the Invasive Potential of Non-indigenous Plants and Plant Pests in the United States. He has served on the editorial boards of *Ecology* and *Ecological Monographs*, *Oecologia*, *Ecological Applications,* and *Biological Invasions.* He also served on the Scientific Committee for Problems in the Environment (SCOPE) Executive Committee, and was a member of the Board for the Global Invasive Species Programme (GISP) until 2003. He is currently a member of the International Union for the Conservation of Nature (IUCN) specialist group on invasive species.

Richard is a featured speaker at the Plenary Session of the 2010 Joint Annual Meeting of the Society for Range Management and the Weed Science Society of America, 7–11 February 2010, in Denver, Colorado. In an interview with Richard we obtain a better understanding of the mechanics of invasive weed species on our range and farmlands.

Question: You have an extensive insight into the conditions that promote plant invasion of a species. What do you consider to be the most likely historical cause of some of the plant invasions into our ecosystems?

Answer: Causes (plural), rather than cause (singular), are the basis of all invasions, and in the case of invaders in western grasslands, some of these causes predate history and are extensively embedded in the evolutionary history of our native species as well as the nonnative species that have become invasive.

For example, the high vulnerability of the steppe in the Intermountain West stems in part from the lack of large herds of trampling, grazing mammals, such as bison, throughout the Holocene. The paucity of these large grazers led to the persistence, if not the emergence, of the native bunchgrasses (e.g., *Agropyron spicatum, Festuca idahoensis*) that dominated the steppe before European settlement in the 19th century. Caespitose grasses, which lack rhizomatous growth, and consequently do not regrow readily from plant fragments, were particularly vulnerable once large, trampling mammals (primarily cattle but to a lesser degree horses and sheep) arrived. In contrast, many of the introduced grass invaders, such as *Bromus tectorum* and *Bromus madritensis* var. *rubens*, are annual. But equally important, they evolved in their native Eurasian ranges with recurring disturbance, such as by trampling, grazing mammals (both feral and later domesticated species). Varied features of their life histories have made them quite tolerant, if not dependent, on the environment that was imposed rapidly in the Intermountain West with agriculture and especially with the introduction of livestock. These species and others were, in effect, preadapted to the environment that was imposed in the Intermountain West (and elsewhere) in the last 150–200 years.

Annual bromes and most other invasive grasses in the West arrived mainly as contaminants in cargo. But the major cause of introduction and spread of invasive plants in the United States has been through deliberate introductions of species that someone thought had a useful purpose. Of course, the list of useful, even essential, species introduced for agriculture in the United States is long: e.g., wheat, rice, cotton, and soybeans. Unfortunately, some other species have formed roles in North America that were not foreseen: e.g., kudzu, European barberry, Johnsongrass, and Chinese tallow tree. The once widespread adoption of these species in the United States as crops has meant that they were deliberately spread far and wide. So, by the time these species were recognized as invaders, they each resided on many sites from which their eradication today seems to some impossible or at least prohibitively expensive.

In summary, the causes of plant invasions begin with the evolutionary history of the plant invaders themselves in relation to the evolutionary history (and later cultural history) of the regions into which these species were introduced. Coupled with this evolution are the categories of plant introduction: accidental introductions in all manner of cargo (including as seed contaminants in imported seed lots), and the bigger source, species' deliberate introductions for some erstwhile purpose (forage, timber, fuel, seasonings, or ornamentation).

Without getting into a political debate, are there more or fewer numbers of plant invasions today than there were 100 years ago?

More. And there are certainly more in the Western half of the United States than 100 years ago, simply because the volume of commerce by which plant invaders have arrived and spread has increased so much in the last 100 years. More invasions have also arisen in the Eastern half of the country for the same reason—more international commerce translates into more opportunities for invasive species to arrive as "hitchhikers" in cargo. And the list of species that have been imported deliberately, especially as ornamentals for indoor and outdoor planting, has also increased. This trend has taken on new significance in the last 20–25 years as more species have been imported from the Chinese mainland, a region from which plant importations were essentially nil after about 1930 until the mid-1980s. No one would deny the aesthetic value to the US public in cultivating species newly introduced from China or elsewhere. But this opportunity needs to be weighed against the hazard of bringing into the country the next Chinese tallow tree (*Triadica sebifera*) or Japanese honeysuckle (*Lonicera japonica*).

What do you consider to be the most potentially damaging plant invasion on the farmlands and rangelands of the United States and the world today?

Any answer here can be scaled with different metrics: e.g., what is the most damaging in terms of total area now invaded or the total financial loss caused or by other measures? Answering this question for the world becomes very difficult because the data (area invaded and financial cost, even risk to human health) become difficult to impossible to obtain currently.

Even in the United States, we have not done a good job so far in estimating the costs of these invasions and our estimates of area occupied are of course hampered by our inability to measure the degree of occupation across the invaded range (e.g., does the invader dominate a site?, occur commonly in it?, or is it simply present?).

So, any comment I make here is a rough estimate and others (depending on the region of the country they are familiar with) may assemble a different list. Among the most damaging are *Bromus tectorum*, *Cenchrus ciliaris, Centuarea* spp., *Euphorbia esula*, *Avena fatua, Salsola iberica, Sorghum halepense*, and in arable fields, *Convolvulus* spp.

I hesitate to assemble a list of "the worst invaders in the world" since attempts at this list are frequently formed, but I concentrate here on the horrific plant invaders in the tropics and subtropics. These species, in addition to covering much area and extracting much from local economies to combat them, also inflict a huge level of human suffering on those who can least afford to lose crops, pasturage, or access to fishing grounds because of invasive plants. This list includes *Lantana camara* (lantana), *Chromolaena odorata* (Siam weed), *Mimosa pigra* and *Miconia calvescens*, and of course *Eichhornia crassipes* (water hyacinth).

What is the impact of urban expansion (ranchettes) on the spread of invasive plants into the open spaces of our range and farmlands? How do we inform these people of the potential problem?

Urban expansion, in the form of small property holdings within areas that were once isolated, is a problem, but we lack quantification of this hazard (e.g., compared to isolated ranches and farms that were rapidly established in the 19th and early 20th century). For instance, the owner of a "ranchette" may not be directly involved in agriculture (crop production or livestock raising), so the opportunity to introduce potentially invasive species may be largely limited to the escape of harmful species introduced in landscaping. That risk is conceptually the same as the escape of potentially invasive species at the margins of large urban areas, but as I stated above, we have yet to quantify this risk.

What is the current most effective means of controlling plant invasion into our farm and rangelands?

Prevention of the inadvertent transport of plant invaders into new sites is the most effective. Much of the spread of an invasion is facilitated by our inadvertently spreading the species in or on farm machinery or in hay or seed sown for range restoration that has currently acceptable levels of seed contaminants. Although it is true that livestock can transport seeds (e.g., sheep fleeces have been blamed for spreading weeds for centuries), the numbers of seeds or other propagules spread by animals are often too small to establish a population (i.e., below the minimum viable population size for a founder population). Admittedly, we do need better quantification of the role of all these modes of transport.

What would you consider the ideal means of controlling plant invasions?

Most effective control arises through continual application of a three-tier process. First, prevent the introduction of plant invaders, whether at the nation's borders or more locally on individual farms and rangelands. This process begins with the effective quarantine inspection and interdiction of potentially invasive species at the nation's ports of entry—this task is performed by USDA Animal and Plant Health Inspection Service (APHIS). A nonnative species stopped at the border has no opportunity to form small, cryptic populations from which it will spread in the new range. Although inspection and interdiction is most effective, these are daunting tasks. A comprehensive inspection of incoming international cargo for accidentally introduced species, known or suspected of being invasive, is required. To some degree, the success of this approach is a direct function of the number of inspectors (and their training) at the border. Members of APHIS certainly understand their important responsibility here, but the usually cited number is that only about 2% of general (nonhigh risk) cargo containers are given any inspection for pest species. Furthermore, a pest species must be in a form that can be reliably recognized. Most living plants (i.e., in raw numbers of individuals) are transported internationally as seeds/corms/bulbs or tubers; important here is that these imported plant products be accurately identified. The United States once trained a corps of expert seed analysts who inspected agricultural commodities for extraneous (and potentially harmful) species; yet today few can accurately cope with the extraordinary diversity of species that arrive as cargo contaminants. This work is time-consuming and can still provide inconclusive results; all the while the importer expects delivery of the cargo without unreasonable delay.

Ironically, the larger task for APHIS is dealing with plants that arrive as deliberate introductions. The huge acceleration of international trade in the last 60 years has meant that many more areas overseas serve as donor regions for plants being deliberately introduced into the United States. Here again, APHIS has the responsibility to determine which among these imported species could present a hazard. Weed Risk Assessment (WRA) is used by APHIS and the quarantine services in other countries to determine the risk of a proposed species for importation becoming a "weed," i.e., problematic, including becoming invasive. The problem here is that aside from the difficulty of placing a quantitative value on this risk for any species (or even a semiquantitative risk, such as "as hazardous as species X, or no more hazardous than species Y"), for some species the requisite information to form an assessment is unknown. For example, for many species proposed for importation from China, we know little or nothing about their ecology, aside from the most rudimentary information on their native ranges. An ideal system would seek out that information for a WRA and then have additional screening for species with equivocal assessments that involves an experimental protocol that is science-based, repeatable, transparent, and prompt.

The second-tier involves Early Detection/Rapid Response, which involves frequent surveys at any scale within a potential new range for newly arrived species that are establishing populations outside cultivation. Once detected ("Early Detection" is the ideal but often a species will have been in a new range for years before it is detected) and determined to be a potential hazard, Rapid Response involves the application of any tools that will eradicate all populations of the species in the new range.

The third tier involves control; i.e., checking the growth and spread of populations of a species for which eradication is judged to be too difficult (e.g., too expensive, too hard to find and destroy all the populations, or already too extensive in its new range). Essential here in the ideal application of control is the realization that control is a permanent commitment of labor and money. Given that the species cannot or will not be eradicated, it must be kept at an acceptably low level. Any suspension of control risks the invader resuming its proliferation in numbers and spatial distribution.

What is your assessment of the effect of global climate change on plant invasion?

Plant species can and will continue to respond to changes in global/regional climate, so it is safe to predict that plant invaders will correspond as well. Although the evidence is largely anecdotal that the ranges of some plant invaders have already changed, there is little question that it can happen and will increasingly complicate the ability to predict future ranges for newly introduced species as well as long-term resident invaders.

What are some of the questions or challenges that the Society for Range Management and the Weed Science Society of America should be aware of and maybe work toward developing a solution?

I think the membership in both societies needs to consider new approaches (new tools, new tactics, new strategies) or at least new variants of current approaches for combating invasive species. It is tempting to assign a standard prescription (e.g., herbicide application) to new invaders as well as recycle older approaches for chronic problems, even when a careful evaluation of the success (or lack of success) of these approaches suggests a fresh start is warranted. (In addition, careful critical evaluation of long-held policies and procedures is also important.) For example, in my opinion, decades of attempting to combat the huge invasions by invasive grasses (e.g., *Bromus tectorum, B. madritensis* var. *rubens, Cenchrus ciliaris, Eragrostis lehmanniana*) in the West with controlled burning, local use of herbicide, chaining of native woody species, and broadcast sowing of nonnative grasses and dicots, has not achieved either grassland restoration or even the emergence of sustainable, productive rangelands. Needed then are new ideas of potentially more effective tools and their critical evaluation.

For example, the United States has long been reluctant to pursue biological control species for invasive grasses among these pests' microbial parasites. Caution in this line of investigation is certainly justified: inadvertent release of a microorganism that underwent a host extension onto one of our crop grasses (corn, wheat, barley) would be catastrophic. But while caution is justified, a virtual prohibition on exploring this line of research greatly hampers what could become our best future weapon against species that have proven extremely resistant to traditional tools. Furthermore, a renewed effort is needed to find new tools, whether those include microorganisms or not. Further challenges—which we should view as opportunities—come from our need to develop more effective control strategies, e.g., recognition.

Interview by Gary Frasier, co-chair of the Public Relations Committee, 2010 Annual Meeting of the Society for Range Management and the Weed Science Society of America (gfrasier@aol.com).