

Training Environmental Managers to Control Invasive Plants: Acting to Close the Knowing–Doing Gap

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Many conservation land managers working with invasive plants rely largely on their own experience and advice from fellow managers for controlling weeds, and rarely take into consideration the scientific literature, a concrete example of a knowing–doing gap. We argue that invasion scientists should directly teach managers best practices for control. In 2013, we created a training program on five invasive plant species, specifically tailored to Québec (Canada) environmental managers. The course material was science-based, and included details on methods and costs. Here, we explain how this idea emerged, how the program was constructed and which types of managers were targeted. With modest resources, we reached 163 managers in less than 18 mo, who collectively oversee invasive species management for 41% of the Québec population. We presented factual information for all control methods, giving the environmental managers the tools to critically and objectively assess various options. Participants especially appreciated the highly practical content of the training and that they could submit their own invasion case for discussion. This program represents significant progress in narrowing the knowing–doing gap associated with the control of invasive plants in Québec, and we encourage such initiatives elsewhere for all fields of invasion biology.

Key words: Certification, education, invasive species, research–implementation gap, science communication, science-based management.

In his recent editorial published in *Conservation Biology*, Ron Abrams (Dur Associates, Inc.) asks why biologists should help people understand their scientific literature. He argues that “in conservation biology, perhaps more than any other scientific discipline, professionals should be open to simplifying their scientific language so their work is generally accessible” (Abrams 2015, p. 973). This is wise advice: applied conservation research that does not reach its target audience (potential users) has been conducted in vain, representing a loss of money, time and effort, and a missed opportunity for improving environmental health. This so-called “knowing–doing gap” has frequently been reported as a major issue hindering the incorporation of research into practice (Arlettaz et al. 2010), especially for the control and management of invasive species (Esler et al.

2010; Hulme 2003; Shaw et al. 2010; Stocker 2004). This has recently been highlighted for environmental managers working with invasive plants in California: practitioners essentially rely on their own experience, advice from other land managers, and Web sites for controlling weeds, and rarely take into consideration the scientific literature, although nearly half hold master’s or doctoral degrees (Matzek et al. 2014). Invasive species managers working for The Nature Conservancy, one of the largest landowners in the United States, are apparently skeptical about academic research with respect to their actions on the ground. They are more likely to value personal and peer knowledge, and first-hand management experience than journal publications (Kuebbing and Simberloff 2015). This situation can be attributed to the disengagement of managers with scientific research, and to a mismatch between the type of research conducted by invasion biologists (essentially fundamental) and the needs of practitioners (essentially applied), a clear example of a knowing–doing gap (Matzek et al. 2014, 2015).

To correct this situation, Matzek et al. (2014) suggest that invasive species scientists present papers at symposia attended by managers, contribute to conservation-focused newsletters, or convene workshops in which scientists, practitioners, and policy-makers could exchange information.

DOI: 10.1614/IPSM-D-15-00033.1

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This would certainly narrow the knowing–doing gap, but we argue that invasion biologists should go a step further by teaching environmental managers the best scientifically sound practices that should be used to control invaders threatening ecosystems, human health, and economic activities. In 2013, we initiated a training program on invasive plants specifically targeting environmental managers in Québec (Canada). To date, 163 people have received our training on weed control, which is noteworthy considering the relatively small community of environmental managers in the province. Here, we explain how this idea emerged, how the program was conceived, and which types of managers we reached.

Genesis of the Program

Our laboratories, based at Université Laval (Claude Lavoie) and Université de Montréal (Jacques Brisson), have jointly developed research projects on plant invaders since the beginning of the 2000s, focusing mainly on common reed, *Phragmites australis* (Cav.) Trin. ex Steud., Japanese knotweed, *Fallopia japonica* (Houtt.) Ronse Decr., and more recently giant hogweed, *Heracleum mantegazzianum* Sommier & Levier, which figure among the most invasive plant species in Québec (Lavoie et al. 2014). Our research projects have touched all aspects of invasion biology, including basic ecological studies on population genetics and reproduction (see for instance Belzile et al. 2010; Groeneveld et al. 2014), dispersal modeling (Duquette et al. 2015; Jodoin et al. 2008; Tougas-Tellier et al. 2015), effects on wildlife (Gagnon Lupien et al. 2015; Larochelle et al. 2015; Mazerolle et al. 2014), and, of course, the development of innovative control methods (Albert et al. 2013; Byun et al. 2013, 2015). These projects were funded by scientific research councils and by government departments (agriculture, environment, transportation), national parks, and nonprofit organizations that were particularly interested in the more applied aspects of our research program. However, much of our applied research was control projects requiring several years to obtain reliable results, and consequently has not yet been published in peer-reviewed journals. Moreover, the substantial amounts of technical experience that we amassed over the years is of low interest to scientific journals, but critical to the success of control programs. Finally, almost all our research has been published in English, which is an obstacle for many Québec environmental managers who often only read French. All these factors enlarged the local knowing–doing gap, and have slowed the application of the research results.

To fill the gap and to develop a local expertise on the control of invasive plants, we collaborated with our partners and initiated joint projects, especially with the Department of Transportation of Québec and several national parks. However, scientific symposia are not appropriate for teaching

detailed best control practices, and do not reach a large fraction of end-users, including citizens concerned with the presence of invaders in their neighborhood. Consequently, since the beginning of the 2010s, we have received hundreds of invasive plant information requests, and dozens of appeals to help locally control plant invaders, which were all declined, as they were not in line with our research mission (no possibility for innovation). In 2013, we faced the fact that there was a clear need for training, but that our communication strategy was not effectively filling this need, and many potential knowledge end-users were not being reached. We thus decided to create a training program better adapted to environmental managers.

Principles of the Program

In October 2013, we formed a think tank composed of students and staff from our respective laboratories to set the basic principles governing our initiative. First, the program had to be scientifically grounded, based not only on our own experience, but also on an exhaustive literature review. Second, each species selected for the program had to be introduced by a concise review of basic biological and ecological aspects relevant to successful control. Third, comprehensive information on the control methods had to be provided to the participants, including legislation to be respected, equipment (and local suppliers), timing of operations, effective herbicide doses, and a series of practical and technical details, drawn from the experience of the instructors and not published. If available, videos were used, since they provide concrete examples: for instance, how to safely extract the roots of a giant hogweed individual (Nielsen et al. 2005) or how to install jute matting over a Eurasian water-milfoil (*Myriophyllum spicatum* L.) population in a lake (Caffrey et al. 2010). Particular attention was paid to the cost estimation for each control method, an extremely important aspect for managers that is rarely documented in peer-reviewed papers (Delbart et al. 2012).

Fourth, we felt that the program would be much more engaging and interesting if managers could submit real-life invasion cases for group study. For each case submitted, we had to present a best management plan during a group discussion session. Fifth, the program had to be officially supported by our universities for enhanced credibility and for the benefit of participants who receive continuing education credits upon completing the course. Finally, we decided to charge participants Can\$250 or Can\$450 (about US \$200 and US\$350) for 1 or 2 d of training, respectively, with a 65% discount for students. This decision was made for three reasons: (1) building the program was expensive (salary of research professionals), with only limited support from affiliated research centers; (2) some expenses had to be covered by participant fees (administrative charges, material, food, classroom, and transportation and lodging of

instructors); and (3) to put a dollar value on a high-quality training offered by experts. Participants were informed that profits, if any, were entirely reinvested in invasive plant research.

Creation of the Program

For the first experience (March 2014), we selected the five species in our areas of expertise for which we estimated there was sufficient demand, i.e., common reed, giant hogweed, Japanese knotweed, and two invasive species of buckthorn, European buckthorn, *Rhamnus cathartica* L., and alder buckthorn, *Frangula alnus* Mill. Eurasian watermilfoil will be added to the editions in preparation (2015 and 2016). We then created the content of the presentations (multimedia slide shows in French), which was subdivided into several parts: (1) identification, (2) biology and ecology, (3) impacts, (4) preventing invasions (through education and legislation), (5) mapping, (6) control priorities, (7) health and safety aspects (especially for giant hogweed, a plant that may cause dermatitis), (8) control methods, (9) monitoring, and (10) case studies submitted by the participants. For each species, all control methods were objectively reviewed and criticized; these measures were (1) mechanical (excavation, girdling, mowing, root extraction), (2) physical (burning, tarping), (3) biological (competition by native plants, grazing), and (4) chemical (herbicide). Biological control using pathogens or insects was not addressed since this method was not an option in Canada for the selected species.

We quickly realized that peer-reviewed papers used to build the program had to be meticulously scrutinized, because (1) the results may not be transferable to different climatic or environmental situations, (2) few simultaneously compared different methods, (3) several were only performed over one growing season, (4) not all laboratory experiments were field-validated, and (5) efficiency measurements were not always comparable (see Delbart et al. 2012 for discussion). All studies were analyzed, criticized, and explained to the audience. We also noticed that the so-called “gray” literature, mainly found on the Internet, was in many cases the only available source of information, especially for control methods little tested but increasingly popular (e.g., tarping), or for large-scale experiments conducted by non-profit organizations, which often do not publish their results in peer-reviewed journals. This literature—supplemented by direct calls to the managers who had conducted the experiments—was used to enrich the training program, but only with caveats concerning the fact that the information had not undergone scientific validation through peer review.

A large amount of time was spent collecting information on the relative costs of various control measures. Evaluating the cost of equipment was an easy task thanks to online catalogues from local or national suppliers. Evaluating the

other costs (labor) was much more challenging. For buckthorns, common reed, and giant hogweed, we drew on our own experience, but for Japanese knotweed and Eurasian watermilfoil, species for which we only studied the ecology and dispersal, collecting cost information required multiple calls to environmental managers with firsthand control experience for these weed species in North America and Europe.

Several months into our preparations, we realized our program was missing a key piece, i.e., some good examples of effective control trials designed by local (Québec-based) environmental managers. Our intent was to provide an additional perspective to the participants, and to show that it is possible to control invasive plants even with modest resources. We thus recruited (through personal contacts) six practitioners to our team, ranging from technicians to research scientists and working for various employers including governments, municipalities, and private companies. Two were specialists for common reed, two for buckthorns, and two for giant hogweed. As of September 2015, the team of instructors is composed of five scientists with doctoral degrees, four biologists or urban planners with master’s degrees, one forest engineer, and one technician. Finally, we received from Université Laval an accreditation for continuing education. The university took charge of the registration of participants, the collection of fees, and the delivery of the certificates and the satisfaction surveys.

Although we were driven primarily by educational motives, we had to take into account the cost of the program before allocating the resources necessary to its creation. We considered our own participation to be part of our work as university professors, so we did not tally our time and effort. All invited practitioners volunteered their services, which helped keep registration costs reasonable. The most important expense was associated with research professionals hired to build the content of the training, including the analysis of case studies submitted by participants. We estimated that each species required between 70 and 140 h of work, depending on the amount of relevant literature, which was greater for some species (e.g., common reed, Eurasian watermilfoil) than for others (e.g., buckthorns). Updating the information for the second and third editions of the training required about 15 to 20 h of work per species.

Participation in the Program

For the first edition (March 2014; Québec City), we offered two choices: a full day on common reed or a full day on buckthorns, giant hogweed, and Japanese knotweed. For the second edition (November 2014; Montréal and Québec City), we added a third option, offering all the species over 2 d. The third edition (April 2015; Rimouski)

targeted environmental managers concerned by giant hogweed in a recently invaded region.

Since we had no budget for publicity, we created a Web site and sent E-mails to various nonprofit organizations and government departments to promote the program. We used our databases on the spatial distribution of invaders and Internet search engines to identify municipalities with serious invasive species problems. Web sites of these municipalities were searched to identify the persons in charge of environmental issues, who were then contacted by E-mail. We also benefited from city association platforms, using these to give Webinars presenting the program.

For the first edition, the 71 available seats were filled within 6 d of opening the online registration, confirming the need for invasive plant control training. The second edition attracted 80 participants, and the third 24 participants, for a total of 163 different people for the first three editions. Registration fees largely covered the cost of the creation of the program (research professionals' salaries), and the profit was entirely reinvested to improve the content of subsequent editions. Giant hogweed was the species with the highest number of participants (115), followed by common reed (97) and buckthorns and Japanese knotweed (91). Participants from government departments (agriculture, energy and natural resources, environment, transportation) formed the largest proportion of our clientele, followed by municipal employees, nonprofit organization managers, and private consultants (Figure 1). The program attracted representatives from 23 different municipalities, from very small (Saint-Guy: 91 inhabitants) to very large (Montréal: 1,649,519 inhabitants), with half (11) having more than 18,000 inhabitants. Altogether, the population of these municipalities totaled 3,240,000 inhabitants, i.e., about 41% of the population of the province of Québec (Statistics Canada 2015).

A DVD with copies of each presentation was given to all participants. Thirty case studies, submitted to the instructors for analysis prior to the training days, were also discussed. Most were for common reed (21) and Japanese knotweed (7), which probably reflects the size of the problem caused by these species in Québec. In comparison, buckthorns and giant hogweed are relatively recent invaders in the province. It was a challenge for the trainers to propose solutions. As one of the instructors said: "this was an excellent way to get us out of our comfort zone." This part of the training was greatly appreciated by the participants, especially those in need of management strategies, as it proved our desire to address their particular needs. However, instead of proposing a single solution, we provided a range of options, with their advantages and disadvantages. Managers could then select the optimal solution depending on their circumstances and budget.

A survey sent out by E-mail to evaluate the participant's experience after the first two editions received response

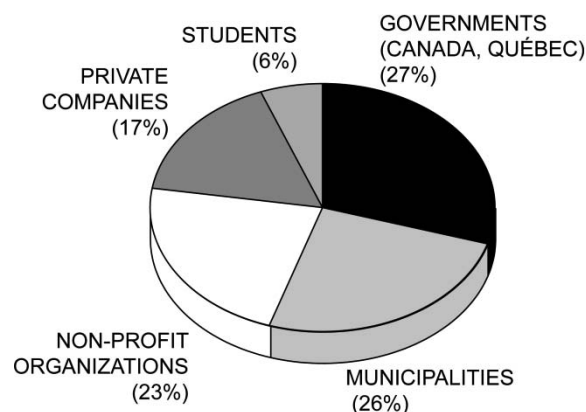


Figure 1. Employers of the participants of the first three editions of the invasive plant training program offered by Université Laval and Université de Montréal to Québec environmental managers.

rate of 80% (no survey was sent following the third edition). Participants were highly satisfied overall, and the satisfaction rate (totally agree) increased from 77% (first edition) to 87% (second edition; Table 1). The participants particularly appreciated the level of expertise of the instructors. The overwhelming majority (totally agree: 97% for the second edition) felt that the information provided corresponded to their needs, a key element for narrowing the knowing–doing gap. Only 4 out of 121 would not recommend the training to others (none in November 2014). More than 350 comments were written by the participants, mainly on aspects they appreciated, such as case studies (35 specific comments) and the highly practical content of the training (22 specific comments). One participant wrote: "I particularly appreciated the professionalism of the educators, the practical content of the training, the originality of control methods, and the fact the educators highlighted uncertainties on the effectiveness of some methods. The case studies were particularly informative." On the other hand, some participants (10 specific comments) criticized the insufficient time for questions and networking. One participant wrote: "You neglected the networking dimension between participants. These participants often have highly valuable knowledge that could be shared during the training to improve the experience." This indicates that additional interactions with instructors and between managers could potentially add a valuable dimension to the training.

It is noteworthy that many managers initially had very high expectations regarding the control of invaders, as suggested by personal interactions between managers and educators and submitted study cases. Of course we did not discourage ambitious control projects. However, we emphasized that for many species, especially those established for several decades and spreading vegetatively, the question is less "Can we eradicate?" (permanent elimination of all

Table 1. Results of the satisfaction survey sent to the participants of the first two editions of the invasive plant training program offered by Université Laval and Université de Montréal to Québec environmental managers.

Training edition Affirmation (original French version in parentheses)	March 2014 (n = 57 responses)			November 2014 (n = 64 responses)			
	Totally agree	Partly agree	Partly disagree	Totally disagree	Totally agree	Partly agree	Partly disagree
	%						
The theoretical content was well developed. (Le volet théorique était bien développé.)	77	21	2	0	89	11	0
The case studies were appropriate. (Les études de cas étaient appropriées.)	65	32	2	2	81	19	0
The instructors knew their subjects well. (Les formateurs connaissaient bien le sujet.)	81	16	4	0	95	5	0
The instructors were in touch with my needs. (Les formateurs étaient à l'écoute.)	91	7	2	0	97	3	0
The training was dynamic and interactive. (La formation était dynamique et interactive.)	79	18	4	0	77	19	5
The material was relevant. (Le matériel pédagogique était pertinent.)	79	18	4	0	81	19	0
The content of the training will be useful for my work. (Le contenu de cette activité sera utilisable dans mon travail.)	68	26	2	4	88	13	0
I would recommend this training. (Je recommanderai cette formation.)	77	19	0	4	89	11	0
Overall satisfaction (all affirmations)	77	20	2	1	87	12	1

individuals from a specific area) than “Can we stop the progression?” or “Can we reduce the number of individuals to an acceptable level?” The last is probably most realistic considering the budgets available for control.

Future Developments and Conclusion

Future training sessions will include field trips to visit invasive species control projects. Other highly problematic species will be added to our trainings, including native plants such as common ragweed (*Ambrosia artemisiifolia* L.). Several nonprofit organizations complained about course fees; in response, we will be offering lower-cost Webinars. Although Webinars cost less, they probably do not offer the same total learning experience as live events, and networking possibilities are more limited. On the upside, Webinars are a cost-effective way to provide course material updates to past participants, which has been frequently requested.

In conclusion, we have significantly narrowed the knowing–doing gap associated with the control of invasive plants in Québec. With modest means, we reached a large number of managers, who represent a large fraction of the population, within a very short time period. Participants were highly satisfied and felt that the course content was useful for their work. Several initiatives have since been taken as

a result of the training, including a total eradication project for giant hogweed in the Bas-Saint-Laurent region, where the third edition of the training was held. The team of instructors found the experience extremely rewarding, even if the academic system poorly recognizes the value of this type of knowledge transfer (Arlettaz et al. 2010; Shanley and López 2009). Our experience suggests that similar programs could easily be implemented in other parts of the world. We encourage invasion biologists to develop their own programs, according to their expertise: to paraphrase Arlettaz et al. (2010, p. 841), “a small effort, such as the one illustrated here, can make a huge difference for biodiversity.”

Acknowledgments

This training program on invasive plants was financially supported by the Centre de la Science de la Biodiversité du Québec, the Centre de Recherche en Aménagement et Développement de l'Université Laval, and the Institut de Recherche en Biologie Végétale de l'Université de Montréal. We are grateful to Patrick Boivin, René Charest, Marie-Josée Coupal, Elisabeth Groeneveld, François Hébert, Sam Karathanos, Benjamin Lelong, and Stéphanie Pellerin for their tremendous contributions as instructors, and to Isabelle Boutin and Renée Hamel (Université Laval) and Guylaine Morrier (Centre Intégré de Santé et de Services Sociaux du Bas-Saint-Laurent) for their help with logistics.

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Received July 20, 2015, and approved October 27, 2015.

Associate Editor for this paper: John A. Randall, University of California, Davis.