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# A heuristic framework for invasive species research planning and measurement. Developing an invasive species research strategy in Tasmania.

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## Abstract

Invasive species research strategies can vary widely in their approach; there are a myriad of ways to organise research topics. We propose a simple approach to making investment decisions for invasive species research using stages of the well-known Generalised Invasion Curve to generate heuristics corresponding to the four stages of the curve plus a cross-cutting theme. Learning from success and failure is a vital part of each stage as this potentially improves practice in all phases of invasive species management. Most strategic approaches to invasive species management emphasise the need for more focus on the early stages of the invasion curve and Australian governments have previously flagged their intention to favour funding for invasive species management towards the early stages of invasion as well. Our approach for structuring research planning in this field provides a way of easily measuring the distribution of research effort across all phases of invasive species management.

## Keywords

Research, framework, government, invasion curve, prevention, eradication, containment, asset protection, projects, lesson learning, heuristic.

# Introduction

Invasive species research is integral to making advances and improving practices. Research results provide the cornerstone of evidence-based decision making. Preparing a research strategy should enable consideration of priorities within the context of available resources. The danger in the absence of a research strategy is that resources can be dissipated amongst too many competing priorities in areas as different as policy, on-ground control methods or communications. Research can therefore become ad hoc, under-resourced or subject to lack of commitment to complete projects. A strategy can help to 'lock in' directions and resources.

This paper originated in the Tasmanian Government in 2015 and was developed at a time when Biosecurity Tasmania was able to transition from a major focus on the fox program to being able to consider a wider range of other existing and emerging threats.

For the purposes of this paper, invasive species will comprise invasive alien species of plants or animals that pose economic, environmental or social impacts.

Funding for research can be limited, particularly for fields where outcomes have high public value but low commercial value. A good research strategy with clear, achievable goals, targeted to the right area to ensure maximum benefit, is very important to guide and explain decisions that identify and pursue specific research objectives. Yet there is little guidance available for a jurisdiction in framing an Invasive Alien Species (IAS) research strategy, nor any common approach to be found in journal articles or documents on websites. Examples of different approaches can be found in the literature. These range from the more subjective method of identifying project priorities according to the expertise and interests of research team members through to a more strategic approach such as a gap analysis of a theoretical system framework (such as Grove 2004 in a forest ecosystem). Another might be driven by priority invasive species, leaving it to the researcher to devise the detail (Invasive Plant Council of British Columbia 2009).

The design of a research framework may also be influenced by immediate requirements for knowledge to support or enhance current practices. Such requirements may range across a variety of topics such as finding improved techniques for poisoning or trapping invasive vertebrates, improving detection, monitoring and surveillance methods, documenting impacts of invasive species and assessing the risk that new or anticipated incursions will impact on productive and environmental values. Research questions also will arise around better decision-making processes and ways of improving community engagement.

In any jurisdiction framing a research strategy for IAS, there are pitfalls that would be recognised by most government agency managers. A research strategy, for example, could tend to be heavily influenced by the expertise and interests of its research staff that could result in important gaps. It may also be influenced by legacy projects and programs that may work against a fresh objective approach.

We could find few explicitly framed research strategies, as mostly, research directions are included in generally worded sections of invasive species management strategies (for example: Norwegian Ministry of the Environment 2007; Department of Environment, Food and Rural Affairs 2008; Hubo and Steinmann 2004). Ferris and Bainbridge (2005) in a strategy for non-native species research framed the questions more according to techniques available for interrogating problems. If there is a general theme discernible in these strategies they repeatedly mention work on surveillance, invasion pathways and knowledge transfer between scientists, managers and practitioners.

Research directions are set at different governance levels. At the broadest level the international focus on the prevention of establishment, surveillance and understanding invasion pathways is a priority under the Convention on Biological Diversity (CBD) (Convention on Biological Diversity 2012), Aichi Biodiversity Target 9. This states that 'By 2020, invasive alien species and pathways are identified and prioritised, priority species are controlled or eradicated, and measures are in place to manage pathways to prevent their introduction and establishment'.

The Commonwealth Government is responsible for reporting Australia's progress against targets. Australia's research priorities are canvassed in two major programs and strategies (Rural Industries Research and Development Corporation 2010, Department of Agriculture and Water Resources 2016).

Under the umbrella of the CBD, one of the ten strategic responses in the Global Strategy on Invasive Alien Species, in addressing the problem of invasive alien species, is in developing a research capacity that focuses on building collaborative and institutional frameworks, improving our understanding through such things as assessment and prediction, managing through risk assessment, and developing improved eradication techniques.

At another level, a top twenty IAS issues list for the EU (Caffrey et al. 2014) originated in workshops representing expertise from biosecurity, risk assessment, policy and economics. The resulting issues led to a key recommendation for each and therefore a clear direction in IAS actions. As expected the actions are over a broad range of endeavour and include actions relating to better funding for research, information exchange between scientists, managers and practitioners, establishment of expert risk assessment panels and work on new risk assessment and early warning systems.

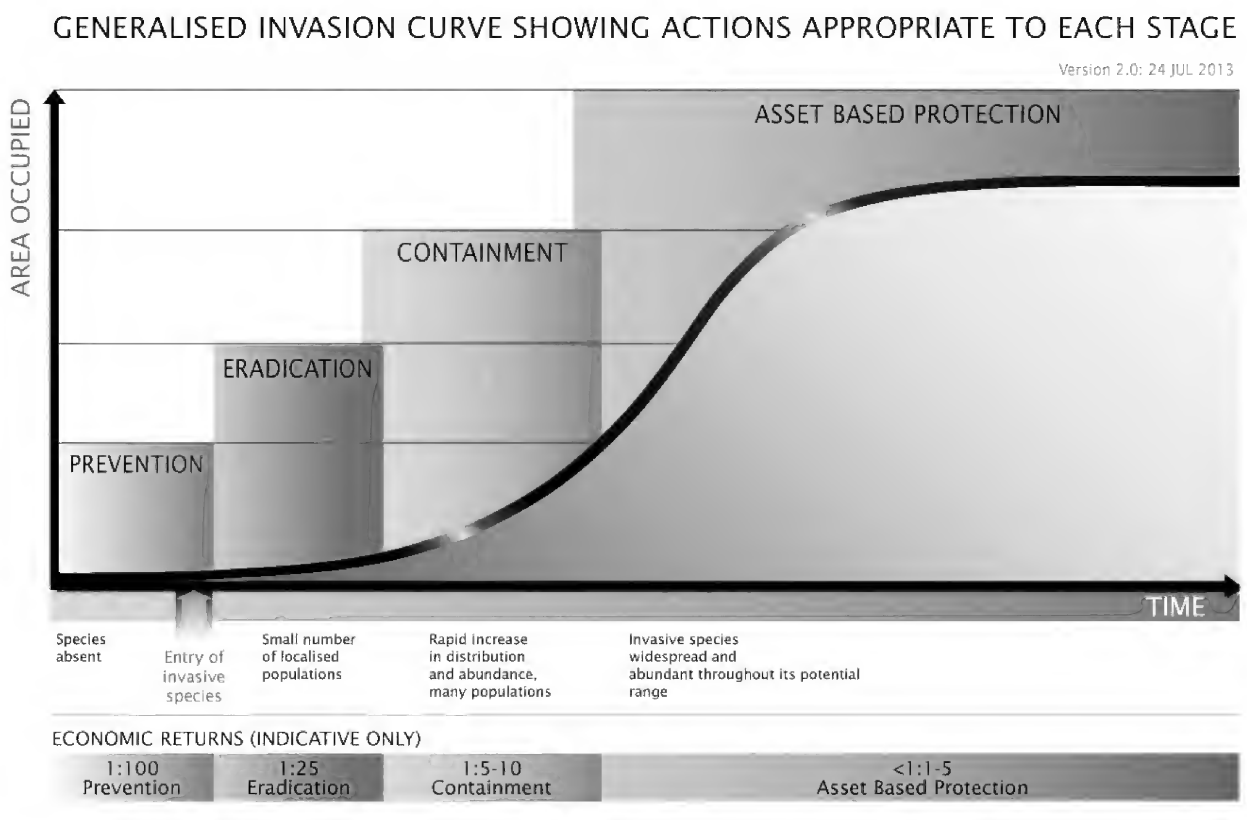
In an Australian national context, Morton et al. (2009) developed a framework for generating research questions looking at effective management of biodiversity (but not so much emphasis on agricultural production values). They divided the issues into four big global themes and then derived a subset list of five issues requiring a particularly Australian focus—the second of these being invasive species. Their highest priority invasive species question was grouped under the global heading of climate change (in synergy with other factors relating to invasive species). This question focused on how to implement detection systems for potential invasive species and the associated response systems. Other invasive species issues identified by these authors related to our understanding of ecosystem resilience and the point in the environmental change process where options are required in response to new ecosystem states. They also identified the need to understand what interventions and responses are practicable under changes in fire regimes and incidence of extreme events.

In summary, there is a wide array of conceptual approaches to planning a research program. The Generalised Invasion Curve (GIC) (Department of Economic Development, Jobs, Transport and Resources, Victoria) is a conceptual approach that is beginning to be used widely in biosecurity for a number of purposes including communication, engagement, strategy and investment decisions. As the GIC is widely used, we believe that this framework can also be used to structure research planning. Ultimately, this will aid decision making at the operational level by virtue of research efforts corresponding to operational priorities identified under a consistent conceptual framework. This paper was previously published as a working paper on an online research network but the interest shown in it warrants formal journal publication.

## Methods

The GIC (Figure 1) was subdivided according to categories from surveillance to asset protection. On the basis of these categories a heuristic composed of several parts was developed. Each part was partitioned according to major phases in IAS research at each particular stage of the GIC. The research phases resulted from the authors' own experience tested in discussion against the experience of our Tasmanian research and practitioner colleagues. A literature scan was conducted for invasive species research strategies to gain impressions from a sample of such documents. The sample is biased towards those more easily discovered in a library and on the internet. A thorough literature review was outside our scope.

The circles from each of the phases are closed by a lesson learning/review and adaptive management recommendation phase that will condition subsequent work, a process emphasised as important by Buckley (2008). It is this latter phase in each of the five stages (including the cross cutting one) that potentially enable the capture of adaptive management lessons to provide feedback to management of invasive species, a process considered to be most important in knowledge gap-filling (Roy et al. 2009).




Source: Department of Economic Development, Jobs, Transport and Resources. State of Victoria.

**Figure 1. Generalised Invasion Curve (GIC):** graph showing the different management actions appropriate to the various stages of an invasion, based on the spread (area occupied) of an invasive species.

# Results

Although various conceptual frameworks are proposed in the literature, the approach adopted here uses the stages of the GIC (Figure 1) against which to attribute research topics/questions. Additional broader topics were also added to cover those areas that span all of the stages, such as decision theory and community engagement. The use of this approach is also likely to be consistent with the national research development and extension priorities for invasive plants and animals (Department of Agriculture and Water Resources, 2016) developed under the Intergovernmental Agreement on Biosecurity (Council of Australian Governments, 2012). Thus, under this framework, projects are arranged under five major headings: prevention, eradication, containment, asset-based protection and broader cross-cutting questions. For each of the five major headings we have identified the relevant sequential elements or steps that are integral to biosecurity success (Figure 2). An analysis of these elements/steps when developing a research strategy will help highlight where information or understanding is lacking, and hence develop appropriate research questions.

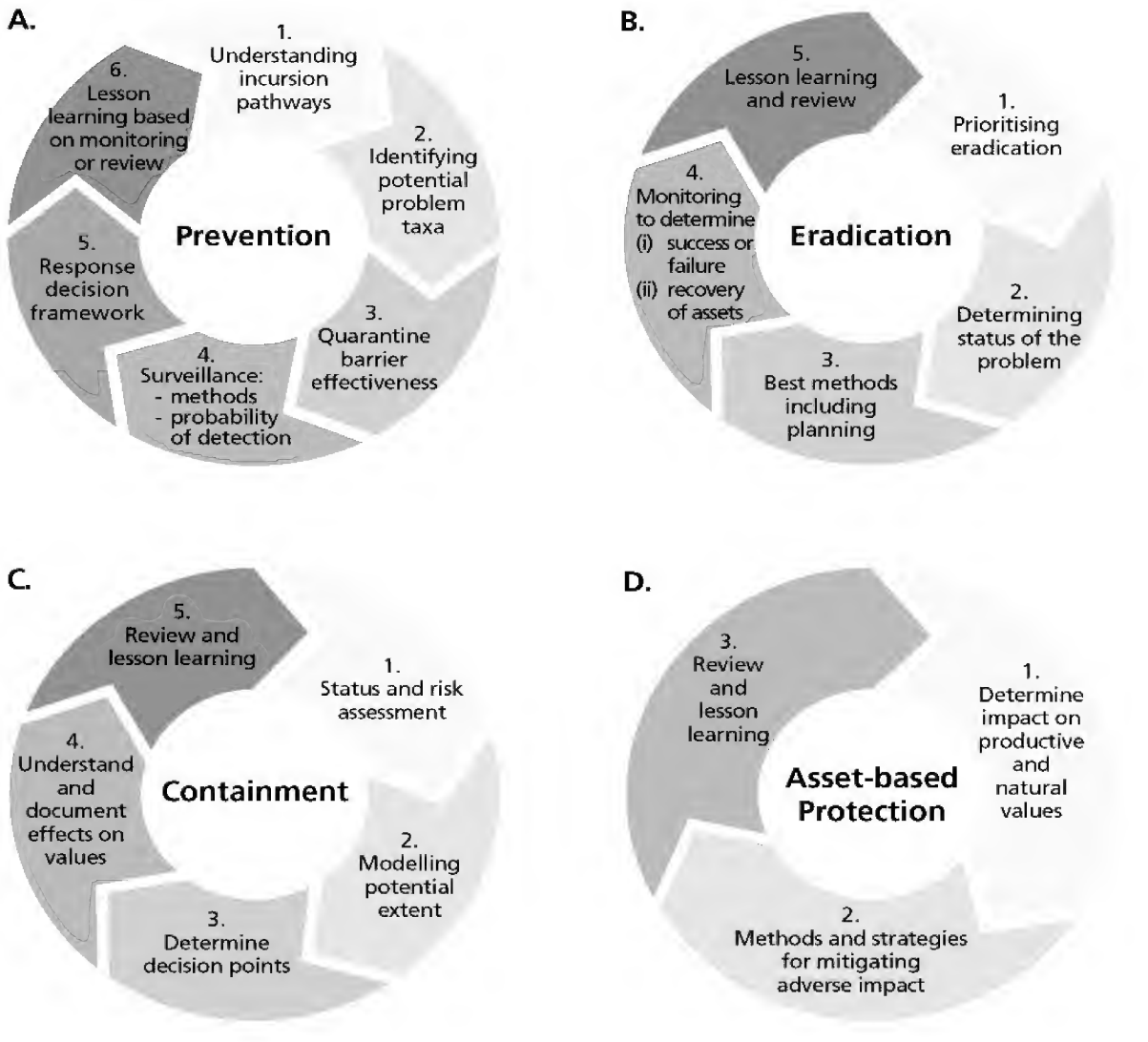



**Figure 2. Research appropriate to the different stages of the Generalised Invasion Curve:** the various sequential research steps necessary for each stage of the GIC in the development of an invasive species research strategy.

## PREVENTION

Developing knowledge to assess and mitigate risks posed by new invasive species entering or having the potential to enter a jurisdiction is a key focus at this phase. It may involve environmental scans to identify new and emerging problem species, entry pathways and improved surveillance and detection techniques and methodologies. A response decision framework is required, and may be developed for one particular species or for a class or category of taxa. The more restricted the number of taxa, the more detailed the response framework can be, as it can factor in known population biology and autecology of the species. Lessons learned will arise from periodically reviewing the efficacy of each of the steps/elements in the prevention loop. Measures of success, or key performance indicators (KPIs) should be identified at the outset of a program to ensure that relevant data is being collected.

## ERADICATION

The eradication phase involves planning an operation based on best available techniques and information. A sobering reminder here is that very few eradication responses in Australia (with some notable exceptions) have been successful. The importance of critically assessing and documenting failures is paramount, so that lessons can be incorporated in such planning. Australia already has national arrangements when responding to significant disease and pest incursions (Council of Australian Governments 2012).

The research component will ensure that any proposed eradication has been prioritised above other potential eradications based on likelihood of success, estimated resources required, and the projected benefits (based on existing or potential values). It is likely that research will be required in order to undertake this prioritisation: monitoring to define the distribution or abundance of a particular species; an assessment of the risk if the population is not dealt with; the rate of spread; and the threats to values.

This research may be carried out at the national level as part of an operational justification under the principles contained in globally agreed Invasive Species Phytosanitary Measures (ISPMs). Research and assessment effort on national priority taxa can be shared amongst other state and national organisations. Such effort, where feasible, may include a cost/benefit analysis of eradication.

Selecting and prioritising candidate species for eradication will be difficult in any case. Many species are usually quickly discounted for eradication as they are highly unlikely to be feasible to eradicate and become even less so as time elapses.

Consideration of the methods to be used in the eradication will depend on the knowledge and experience of the practitioners and will be valuably informed by any published lessons from similar eradications. This makes step 5 especially valuable to all practitioners. Many of the lessons learned will derive from monitoring to determine the success or otherwise of achieving eradication. Declaring success according to Bomford and O'Brien (1995) will depend on the results of monitoring as well as an assessment about the recovery of conservation values or other assets. The nature of success is also somewhat defined in International Phytosanitary Measures.

## CONTAINMENT

Assuming containment means stopping further spread of an invasive species then it can require much the same activities as eradication and hence may be similar in costs. In practice, so-called containment may suppress rather than prevent spread. The approach is open-ended and will require resources and long-term commitment to maintain. Therefore the invasiveness potential and threat potential of the control target and a risk assessment incorporating a cost-benefit analysis is necessary and requires regular review to ensure the decision remains valid. The risk assessment would

typically involve modelling of different scenarios, including potential total extent of occupation should the species become uncontrolled. There is a rich literature on this general component. Decision points that inform the choice of various control actions and methodologies will be required so that confidence can be maintained in sustaining containment. In turn, this will need to be based on monitoring through a targeted survey. Switching between one set of management actions and another should be informed by likely outcomes, costs and implications.

Given the long-term commitment and resources required for containment, a clear understanding of the derived environmental, economic and social benefits is essential; it underpins the strategy. As with all aspects of an invasive species research program, the review and lesson learning phases should result in documented and published information.

## ASSET BASED PROTECTION

The asset-based protection phase refers to the situation where an invasive species has spread beyond the measures that might be applied under the prevention, eradication and containment scenarios and it becomes more cost effective to target efforts to protecting key assets or values from the impacts of the target species. The first focus of research in this phase needs to be on understanding what impact the pest has on productive and natural values. An example of the process for doing this is found in Timmins and Owen (2001). Once this is clearly established then devising methods to mitigate adverse impacts can be done. An assessment of what works and what doesn't, and why, will arise after a period of monitoring that can inform the exercise. Considerable guidance can be found in the principles and examples to be distilled from the extensive literature.

## CROSS-CUTTING QUESTIONS: WHOLE INVASIVE SPECIES PROGRAM

There are research questions that arise in implementing a program that cannot be identified with any one of the phases above. One such cross-cutting issue that is extremely important is finding ways to increase community capacity and building awareness. There is a growing body of work (e.g. Marshall et al 2016, Martin et al 2016, Santo et al 2015, Hine et al 2014, Kruger 2011) identifying the importance of developing a better understanding of the 'human dimension' of invasive species management and the impacts that support, or the lack of, can have on management outcomes. Developing a better understanding of community attitudes to invasive species, control methods, barriers to community led action and developing better community engagement efforts by government are all relevant to any phase of an invasive species program and cannot be confined to a particular phase of invasive species management. Similarly, strengthening social networks and institutions through research to improve stakeholder coordination and identifying barriers to that coordination and collaboration will be important across programs. Other examples of cross-cutting research includes best practice management including new technologies and biocontrol.

## Discussion

We determined that an objective, structured approach to our research plan could be guided by a set of heuristics generated by stages of the GIC. We found this to be a promising approach that avoids such pitfalls as allowing the capabilities or gaps in skills of existing staff to determine the program. Such issues are obviously a consideration, but collaborators can be chosen to balance the in-house skills. For example, in Tasmania, delivery of research outcomes is assisted by accessing specialised mathematical and ecological modelling skills from external organisations rather than attempting to maintain the resource 'in house'.

Collaborative partnerships are extremely important in delivering a research plan, and in applying the resulting knowledge to projects and management. A strong emphasis on the publication of research in peer-reviewed journals benefits the field broadly and contributes to the adaptive management process. Dissemination of the knowledge more widely, in presentations and program publications, allows for experience and lessons learned to be shared, thus benefitting the practice and theory in the field of invasion biology. Collaborative approaches are sometimes endorsed at a high level such as under the National Research Development and Extension Priorities for Invasive Plants and Animals 2016-2020 that emphasised the need for greater coordinated cross-institutional effort to improve research capacity (Invasive Plants and Animals Research and Development Expert Group, 2016).

A research plan will be achieved through the completion of well-defined projects with corresponding project plans (of varying complexity depending on the scale of the project or project prospectuses). The projects will be arranged under five principal strategic themes: prevention, eradication, containment, asset-based protection and cross-cutting themes. Sometimes projects straddle more than one strategic area of activity. Determining where investment is targeted between and within the stages will be subject to external advocacy from industry and community sector bodies as well as from political input. The value of the heuristic is in helping to demonstrate the broad scope of possible research activity thus enabling stakeholders to understand the allocation of research investment.

Finally, we acknowledge that there is a political overlay to the GIC. Some argue that prevention is hard to sell, hard to communicate and may not appeal to political constituencies. Political considerations may push investment to the right-hand side of the curve where operations are costly and in many cases may ultimately be futile but where public demand for investment is high. Prevention is arguably the best value program in invasive species management. Mack and Lonsdale (2002) note that leaving a new immigrant to observe whether it has adverse consequences is problematic because invasiveness is sometimes difficult to predict. They argue that 'delay greatly reduces the prospects for eradication'. However, a pragmatic approach may be to have a deliberate balanced research and management portfolio across the GIC to balance for unavoidable political pulls and community demands with optimum return on investment.

Across a research portfolio, investment in 'blue sky' research might need to be considered where the risk of failure is high but where there is the prospect of high returns on investment if positive results are obtained. This is perhaps balanced against research projects with more predictable outcomes that will lead to incremental gains in invasive species management. Long-term research goals should not be forfeited for short term research investment. Public wildlife and biosecurity agencies need to closely engage with a wide diversity of research providers. For example, current work addressing the meso-predator release hypothesis could have profound implications for invasive species research but this science

is not pursued in government agencies so much as it is in universities. Collaboration between government and universities is therefore important so that the results of such research can be more effectively directed at improving public policy for invasive species.

Our contribution in this paper is in identifying a structure for framing an invasive species research program. We suggest allocating research effort by using the GIC, with its well-defined stages, and using the heuristic diagrams as a guide through the likely research requirements needed within each of the stages. This framework thus serves to identify areas that require research, and acts as a useful way of looking at where research effort is allocated. The research profile of an organisation can therefore be easily generated to depict the distribution of research effort across prevention, eradication, containment and asset protection, as well as cross-cutting issues.

## Notes

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