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The economic cost of managing invasive species in Australia

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Abstract

Like most jurisdictions, Australia is managing a broad range of invasive alien species. Here, we provide the first holistic quantification of how much invasive species impact Australia's economy, and how much Australia spends on their management. In the 01–02 financial year (June to July), the combined estimated cost (economic losses and control) of invasive species was $9.8 billion, rising to $13.6 billion in the 11–12 financial year. Approximately $726 million of grants funded through the Commonwealth of Australia (i.e. federal funding) was spent on invasive species management and research between 1996 to 2013. In 01–02, total national expenditure on invasive species was $2.31 billion, rising to $3.77 billion in 11–12. Agriculture accounted for more than 90% of the total cost. For 01–02 and 11–12, these expenditure figures equate to $123 and $197 per person per year respectively, as well as 0.32 and 0.29% of GDP respectively. All values provided here are most likely to be underestimates of the real values due to the significant constraints of the data obtainable. Invasive species are clearly a significant economic burden in Australia. Given the extent of the issue of invasive species globally, there is a clear need for better quantifications of both economic loss and expenditure in more jurisdictions, as well as in Australia.

Keywords

cost, exotic, impact, invasion, economy

Introduction

Australia is a world leader in biosecurity policy and management, having some of the world's most stringent biosecurity. These controls are necessary to assist protecting Australia's biodiversity, agriculture, and aesthetic values. But like most jurisdictions, Australia is managing a broad range of invasive alien species due to a legacy of both accidental and deliberate introductions. The impacts of many invasive species in Australia are some of the most dramatic and well known globally and include extreme seasonal plagues of rabbits (Hall et al. 1964) and mice (Mutze 1989), dominance within, and turbation of, freshwater systems by European carp (Harris et al. 1998) to the blanketing of southern Australian agricultural landscapes by Paterson's curse, *Echium plantagineum* (Parsons and Cuthbertson 2001).

Of the approximately 2700 exotic plants species now established within Australia, 429 have been declared noxious or are under some form of legislative control (NRMMC 2006) with considerably more subject to eradication and control measures such as plant species listed on the National Environmental Alert List (http://www.environment.gov.au/biodiversity/invasive/weeds/weeds/lists/alert.html). The economic cost of weeds to the Australian economy within agricultural areas alone is estimated to be approximately $4 billion annually (Sinden et al. 2004; BRS 2007). There are more than 80 species of exotic vertebrates that have established wild populations (Bomford and Hart 2002; BRS 2007), with the eleven most problematic species alone having negative impacts estimated a decade ago to cost $720 million annually (McLeod 2004). Invasive invertebrates are estimated to create annual agricultural production losses of $4.7 billion annually (BRS 2007) and cost up to $8 billion annually considering all impacts and expenses (Canyon et al. 2002), with the red imported fire ant, *Solenopsis invicta*, being the target of Australia's most expensive eradication campaign, costing approximately $300 million to date (Keith and Spring 2013).

Surprisingly, given the extent of Australia's issues with invasive species, and the global need to increase public awareness of the issue of invasive species, data of expenditure on invasive species management is difficult to obtain. However, this issue of poor data availability is not just restricted to Australia, and arises from both the difficult nature of costing the expense of invasive species as well as the lack of good data collection by agencies. As an example of a costing difficulty, most herbicides are broad spectrum and they are used to control both native and exotic weeds within the same crop making it difficult to cost the financial implications of exotic species alone. Where data exist they are largely estimates, predominantly associated with agriculture expenditure or loss, focused on individual taxa (e.g. weeds, vertebrates, invertebrates: McLeod 2004; Sinden et al. 2004; Gong et al. 2009), and reported in incompatible formats (e.g. project-level vs aggregated information) making holistic costs extremely difficult to calculate. Regarding data collation, the lack of financial transparency is largely the result of funding being provided by a multiplicity of agencies through a range of funding programs at various levels of jurisdictional responsibilities (i.e. local, state and federal government), or private enterprises with little to no requirement to report such information in a co-ordinated manner. No level of government or any private enterprise details invasive species management as a distinct expenditure, and unlike the European Union (Scalera 2010), Australia has no publically available database that allows holistic quantification of expenditure on invasive species management for any jurisdictional level, for any purpose (e.g. agriculture versus conservation) or for any funding program. As such, it remains unclear just how much Australia actually spends on managing invasive species.

The largest single source of environmental funding within Australia is provided by the federal government and for the last 20 years has been primarily allocated through three programs: National Heritage Trust (NHT, 1997–2008), Caring for Our Country (CfOC, 2008–2013) and the Biodiversity Fund (2011 to current). Additionally there have been two more programs specifically targeting invasive species: Defeating the Weeds Menace (DtWM, 2004–2009) and the National Weeds and Productivity Research Program (NWPRP, 2010–2012). Although some analyses have been conducted to quantify expenditure on invasive species within these programs, for example against weeds for NHT (Martin and van Klinken 2006), the holistic figure of expenditure for all invasive species by these programs is not clear. Here, we provide the first holistic quantification of Australia's economic loss and expenditure on invasive species in terrestrial and freshwater systems by examining data available from annual reports for these programs as well as that from other sources that calculate the economic loss imposed by, and expenditure on, invasive species. We envisage that these data will be useful globally to assist with raising general awareness of the importance of invasive species and biosecurity. Importantly our data do not include diseases or pathogens because management expenditure on these taxa largely do not come from competitive federal grants, and these taxa also cross into the human health arena which is outside of the focus of this study. Where possible we have excluded data for these taxa from cited publications. We also intentionally only conduct analyses at the national level to provide a broad overview of national expenditure for an international audience.

Methods

Holistic economic loss and expenditure

To provide a holistic picture of the economic loss imposed by, and expenditure on, invasive species within Australia we obtained financial data from accessible sources with a key focus on invasive species management or research within the 01–02 and 11–12 financial years (July to June). These reporting periods were used as they were the only years where documents reported some of these data. Data of estimates of economic loss imposed by invertebrates, vertebrates and weeds for 01–02 were sourced from Canyon et al. (2002), McLeod (2004) and Sinden et al. (2004) respectively. Because for invertebrates and weeds there were no documents that superseded those used for 01–02, and because the vertebrate data presented in Gong et al. (2009) was not as comprehensive as those presented in McLeod (2004), the 01–02 data for these three taxa were used again for 11–12 but were adjusted for inflation to 2012. Data of expenditure was sourced from federal grants (detailed below), federal agencies (e.g. Australian National Parks and Wildlife Service), state-level agencies (e.g. Departments of primary industries and conservation), Cooperative Research Centres (CRC's), and reports of farm expenditure. Expenditure by federal and state-level agencies were sourced from Sinden et al. (2004) for 01–02 and Gong et al. (2009) for 11–12, although the data from Gong et al. (2009) was for 07–08. CRCs are funding hubs for research and were chosen because they are the subject of significant funding initiatives and have relatively transparent reporting. Budgets of four CRCs with a primary focus on invasive species (i.e. Invasive Animals CRC, Plant Biosecurity CRC, Weed Management CRC, and Biological Control of Pest Animals CRC) were sourced from annual summary documents accessed from the CRC website: www.crc.gov.au (accessed 29 April 2014). Because only total budget data over the lifespan on CRCs (5–7.5 years) were provided, we divided the total budget for each CRC by its lifespan to estimate the budget for each financial year. Additionally we divided the CRC funding data by whether the focus of each CRC was on animals or plants. Data of economic loss and expenditure on farms for 01–02 were sourced from Sinden et al. (2004), and for 11–12 from the 2013 National Landcare Survey of the impact of pests and weeds on farming enterprises and the costs associated with their control (www.landcareonline.com.au/wp-content/uploads/2013/10/Final-2013-NLF-Survey-Results-Summary.pdf).

Data of economic loss and expenditure were also obtained and summarised for as many other global jurisdictions that we could find. Data were obtained for the USA in 2003 (Pimentel et al. 2005), the European Union in 2006 (Kettunen et al. 2009; Scalera 2010), Australia in approximately 1998 (Pimentel et al. 2001), and for the USA, UK, India, South Africa, Australia and Brazil combined in approximately 1998 (Pimentel et al. 2001). Data of loss and expenditure combined were obtained for Canada in approximately 2000 (Colautti et al. 2006) and Southeast Asia in 2011 (Nghiem et al. 2013). Data of loss and expenditure were also obtained for New Zealand in 2008 (Giera and Bell 2009), for a few species in Germany in approximately 2002 (Reinhardt et al. 2003), and for 12 species in Sweden in 2006 (Gren et al. 2009). Data of economic loss only were obtained for Great Britain in 2010 (Williams et al. 2010), and two estimates were obtained for China in 2000, being of indirect economic loss of forest insects and pathogens (Li and Xu 2005) and total economic loss (Xu et al. 2006). It should be noted that although all of these studies had the same broad goal to quantify the financial cost of invasive species, they differ greatly in methods, assumptions, data availability, and effort expended, and therefore comparisons can only be made very broadly. In all cases, the data sourced relied heavily on surveys and conservative calculations (see details within respective publications), and often did not report on all exotic species within the target group (e.g. vertebrates). Where data ranges were provided, we used the lowest value which further makes our calculations conservative and likely to underestimate real expenditure.

Federal grants

Annual reports and listings of approved projects within the five Australian federal government funding programs were sourced from each program's respective website [NHT (http://nrmonline.nrm.gov.au/catalog), CfOC (www.nrm.gov.au/funding/approved/index.html), Biodiversity Fund (Round 1, 2011–12, www.environment.gov.au/cleanenergyfuture/biodiversity-fund/round-1/index.html#lists)], or reports obtained elsewhere [DtWM (Oliver et al 2008), NWPRP (RIRDC 2010)]. For the NHT, specific investment through the National Feral Animal Control and Weeds Programs was ascertained for each financial year. Because invasive species management also occurs as part of other natural resource management (NRM) activities, project titles and objectives (where available) were assessed for key words including invasive, control, eradication, pest, weed, rehabilitation, restoration and the common or species names of known invasive and pest species to determine the intent of each project. Funding details for project titles that specifically addressed an invasive species issue were extracted and the number and total value of these were calculated for each financial year. In 2002, NHT changed its reporting methodology and no longer produced lists of approved projects. Hence, we were only able to ascertain total values for funding allocated to their Activity Areas (i.e. project-based themes) of "Pests and weeds" and "Significant invasive species". For CfOC and the Biodiversity Fund, project titles and descriptions were similarly assessed to determine whether projects directly addressed an invasive species issue or intended to undertake management actions as part of broader objectives. Although this approach is likely to inflate total investment by including projects if only a proportion of the grant was directed towards invasive species management, we consider that this is at least partially offset by the exclusion of projects that included invasive species management but this action could not be ascertained from the project title or objectives. For example, projects that involved restoration would have certainly included weed management component but these were not included in our calculations. Any artificial inflation would also be offset by our data not including both direct and indirect financial support by partner organisations in each project.

Additional inconsistencies within and among funding sources were encountered that limit the accuracy of the data. First, CfOC funding was allocated through multiple programs, but the allocation and reporting of funding in each program varied making it difficult to maintain a consistent approach to calculating expenditure. Second, was that CfOC adopted a new model with respect to how Commonwealth funds were devolved. In recognition of the regional and local roles that Australia's 56 regional natural resource management organisations play, these were able to secure 3–5 years of funding (base-level funding) to work with local communities to identify and set local priorities for investment. Consequently, comparisons of pre- and post-2008 for base-level funding cannot be made. In subsequent years where base-level funding is included, these data are likely to be inflated as only a proportion would have been used directly for invasive species management. As such, and because base-level funding was often the greatest proportion of the overall funding, we report data with and without base-level funding.

Analyses

Although we preferably would have analysed data down to numerous taxonomic levels (e.g. lifeform: plants/vertebrates/invertebrates or species-level: snakeweed/rabbits/fire ants), we were not able to provide accurate divisions for most data. For example, for the federal grants, there was no way to determine what the focal invasive species was if the name was not in the project title, and such level of discrimination was only possible in the oldest data (NHT). Additionally, funding allocation was problematic in the numerous instances where multiple invasive species were targeted simultaneously (e.g. crop spraying, woodland restoration). Therefore all invasive species are considered together. In addition to basic data summation, Australian data of economic cost and national expenditure were also expressed in some instances per person (Australian citizens) and as a percentage of Gross Domestic Product (GDP: national financial turnover). Australia's population and GDP data were accessed from the Australian Bureau of Statistics website www.abs.gov.au (accessed 29 April 2014). Because population data were obtained only every five years, we calculated data for the other years by averaging data between census years. We present financial data along timeframes both as raw data, and adjusted for inflation to 2012 for total economic loss and expenditure, and to 2013 for federal expenditure. Data were adjusted for inflation using the Reserve Bank of Australia's Inflation Calculator at: http://www.rba.gov.au/calculator/annualDecimal.html.

Results

Economic loss and expenditure

In the 01–02 financial year, the combined estimated cost (economic loss and expenditure combined) of invasive species was $9.79 billion ($12.88 billion adjusted to 2012 values) (Table 1). For the expenditure that we could obtain data for both 01–02 and 11–12 (federal grants, CRCs, state and federal agencies, farms), after adjusting the 01–02 data to 2012 values, there was an increase in expenditure by $639.55 million from 01–02 to 11–12. When we added this figure to the 01–02 cost data with no 11–12 equivalent, after adjusting the 01–02 data to 11–12 values, the total estimated cost (economic loss and expenditure combined) of invasive species in 11–12 was $13.6 billion (Table 1). However, because this 11–12 figure is predominantly reliant on inflation adjusted 01–02 data we expect it to be a great underestimate because we consider it highly unlikely that costs have not stayed constant or decreased. These estimates of economic cost represented 1.37 and 0.92% of GDP in 01–02 and 11–12 respectively.

Expenditure by federal grants

Approximately $726 million was spent by the Australian federal government on invasive species between 1996 to 2013 in the five funding sources, but with base-level

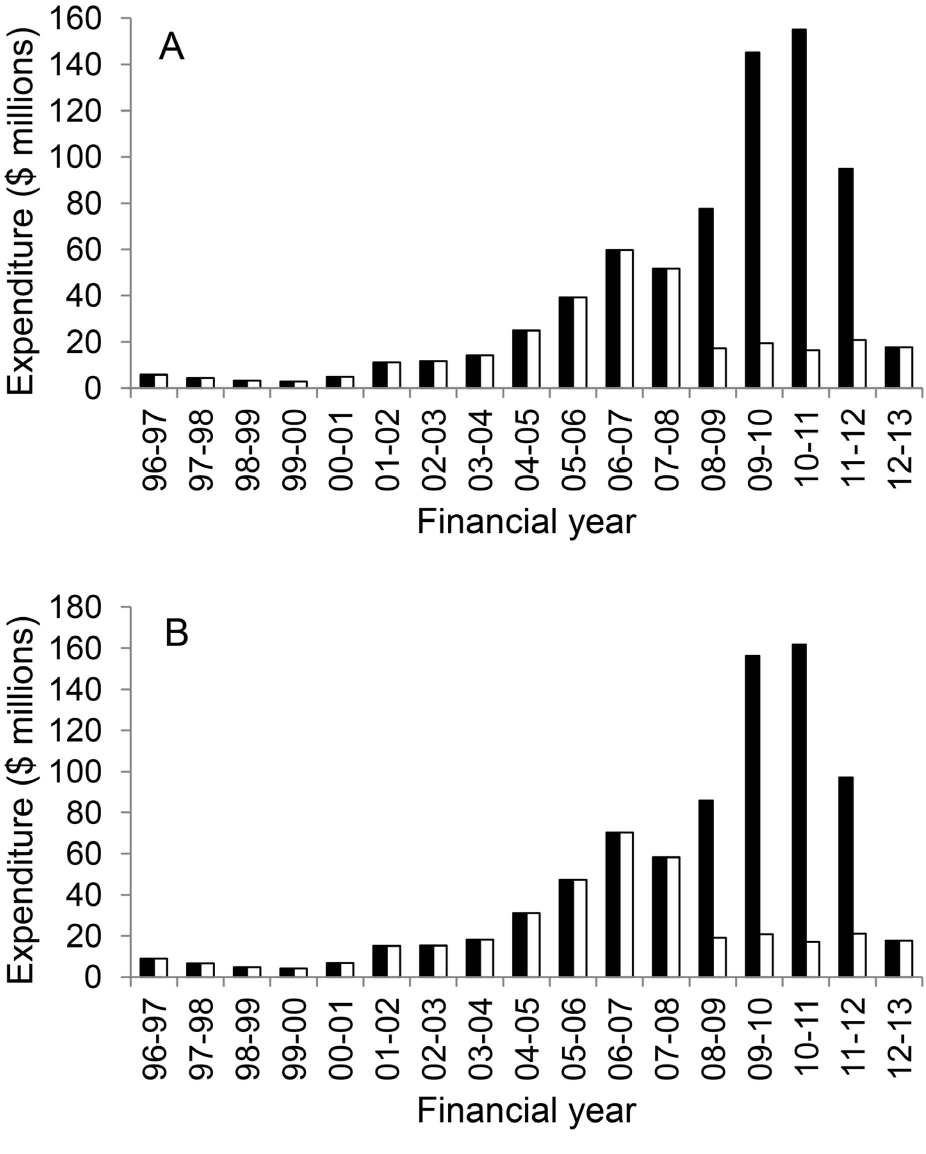

Figure 1. Total expenditure of federal grants per financial year for invasive species management with base-level funding included (black) and excluded (white) using **A** actual data, and **B** data adjusted for inflation to 2013 values.

funding excluded this figure was reduced to $282 million (Figure 1A). The lowest figure spent was $2.9 million in 98–00, and the greatest was $155.08 million in 10–11 with base-level funding included, and $45.6 million in 06–07 with base-level funding excluded. Patterns of expenditure among years were almost identical for raw data and data adjusted for inflation to 2013 values (Figure 1B).

Table 1. Estimated economic loss and management expenditure for exotic species for numerous countries and timeframes. Data of different timeframes are not adjusted for inflation. For reports of individual countries except Australia only the most recent report was used. Reports are listed in order of the year that the data relate to.

Location	Data sources	Description of data used here and applicable year	Economic loss	Management expenditure	Management expenditure as % of economic loss	Economic loss and management expenditure as % of GDP
USA, UK, India, South Africa, Australia, Brazil combined	Pimentel et al. 2001	All data^, for approx. 1998	USD$306 billion	USD$30 billion	8.9	–
Germany	Reinhardt et al. 2003	All data for 20 species, for approx. 2002	EUR€113.4 million	EUR€53.7 million	Not calculated as data are only for a few species	Not calculated as data are only for a few species
China	Li and Xu 2005	Indirect costs only of forest insects and pathogens^ for 2000	¥15.44 billion	–	–	0.01
China	Xu et al. 2006	All data, for approx. 2000	USD$14.45 billion**	–	–	0.01
Canada	Colautti et al. 2006	16 species^, for approx. 2000	CDN$34.5 billion**	–	–	Not calculated as data are only for a few species
USA	Pimentel et al. 2005	Species with data of both impact and control, excluding microbes and disease for approx. 2003	USD$40.31 billion	$USD9.01 billion	22.4	0.96
USA	Pimentel et al. 2005	All data excluding microbes and disease for approximately 2003	USD$88.64 billion	USD$12.03 billion	13.6	1.96
Sweden	Gren et al. 2009	All data for 12 species, excluding HIV, for 2006	SEK1911.5 million	SEK852.5 million	Not calculated as data are only for a few species	Not calculated as data are only for a few species
EU	Impact cost from Kettunen et al. 2009, management expenditure from Scalera 2010	25 species, for 2006	EUR€20 billion	EUR€18.3 million*	Not calculated as data are only for a few species	Not calculated as data are only for a few species

Location	Data sources	Description of data used here and applicable year	Economic loss	Management expenditure	Management expenditure as % of economic loss	Economic loss and management expenditure as % of GDP
New Zealand	Giera and Bell 2009	All data, for 2008	NZ$2454 million	NZ$836 million	34.1	1.86
Great Britain	Williams et al. 2010	All data^, for approx. 2010	£1.68 billion**	_	_	0.07
Southeast Asia	Nghiem et al. 2013	All data^, for 2011	$USD33.5 billion**	_	_	2.61##
Australia	Canyon et al. 2002, McLeod 2004, Sinden et al. 2004	All data, for 2001-2002 financial year	AUD$7.48 billion	AUD$2.31 billion	30.9	1.37
Australia	Canyon et al. 2002, McLeod 2004, Sinden et al. 2004, Gong et al. 2009, 2013 National Landcare Survey & our calculated difference between expenditure in 01-02 and 11-12 for federal grants and CRCs.	All data for 2011-2012 financial year	AUD$9.83 billion	AUD$3.77 billion	38.4	0.92

^ data includes diseases and/or pathogens

* data are for a single funding source, and therefore will be a gross underestimate of the actual figure.

data are older than that for management expenditure but are the most recent obtainable.

** data are both economic loss and management expenditure

average, excluding Myanmar and Brunei

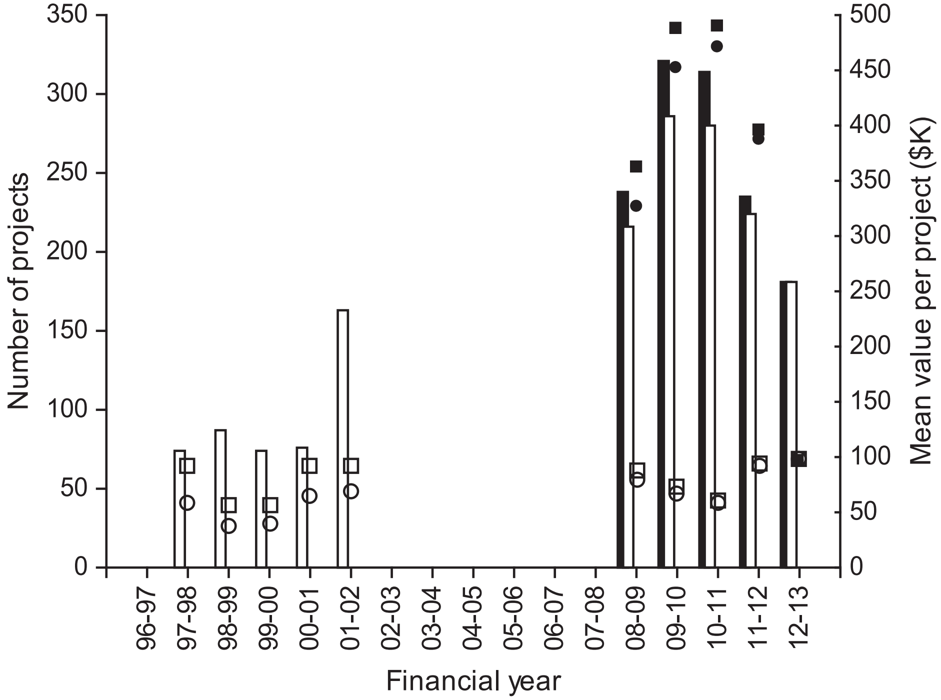

Figure 2. Number (columns) and mean value (points) of projects funded per financial year including (black) and excluding (white) base-level allocations of funding using actual data (circles), and data adjusted for inflation to 2013 values (squares). Missing data could not be obtained.

Overall there was a trend of an increase in the number of projects and the average value of each project over time, with the patterns of value being consistent for raw data and data adjusted for inflation to 2013 values (Figure 2). The pattern of the number of projects funded was similar with and without base-funding, with years up to 2001 having an almost consistent average of 78 projects, spiking to 163 projects in 01–02, and from 08–09 to 12–13 having an average of 258 projects (Figure 2). In the years up to 2002 the average funding per project was \$54K (\$77.5 adjusted to 2013 values), whereas from 09–10 to 12–13 the average project cost approximately \$359K and \$136K with and without base-level funding respectively (\$366.3K and \$83.1K respectively adjusted to 2013 values) (Figure 2).

Of the three funding sources that were not specific for invasive species (NHT, CFoC and Biodiversity Fund), the proportion of total expenditure on invasive species had a clear gradual increase with time (Figure 3). Lowest expenditure was only 1.4% in 99–00, and greatest expenditure (without base-level funding only) was 40.6% in 12–13. Research funding for the four CRCs with a primary focus on invasive species was split almost evenly for animals (42.4 %) and plants (57.6%) across all years (Figure 4), with expenditure on animals being almost all for vertebrates.

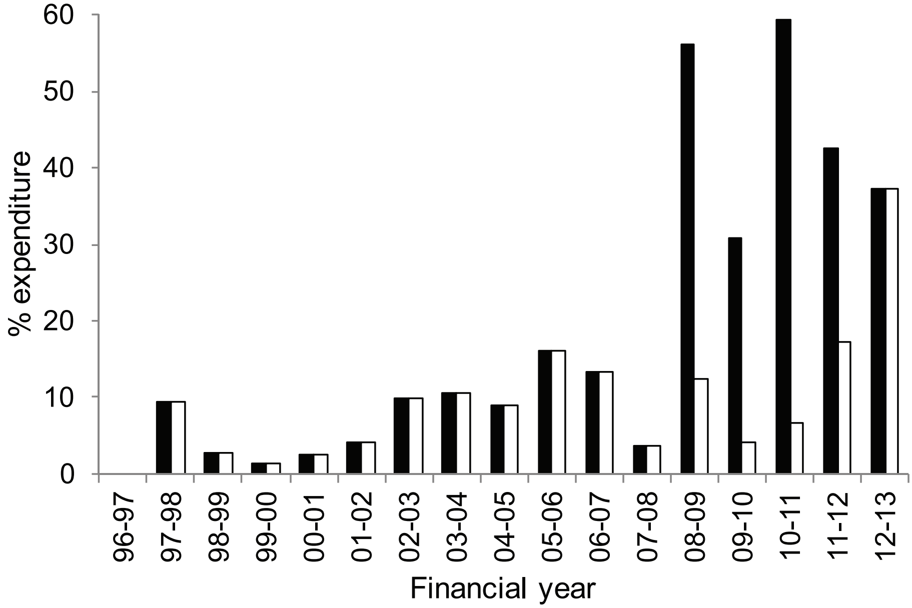

Figure 3. Percentage of total expenditure of federal grants per financial year used for invasive species management with base-level funding included (black) and excluded (white).

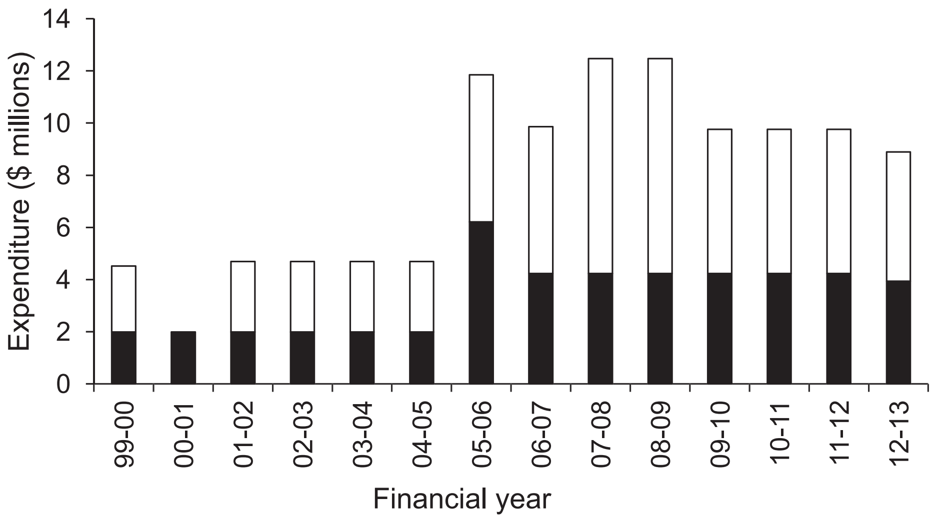

Figure 4. Funding (unadjusted for inflation) supplied to Cooperative Research Centres (CRC) for scientific research focused on invasive animals (black) and plants (white) per financial year. Note that much of the data are uniform across years because yearly data were calculated by averaging the total funding figure of each CRC over its lifespan.

Total national expenditure

In 01–02, total national expenditure on invasive species was $2.31 billion ($3.03 billion adjusted to 2012 values), rising to $3.77 billion in 11–12 (Table 1). Notably, the 11–12 figure is predominantly reliant on inflation adjusted 01–02 data and therefore is expected to be greatly underestimated because we consider it highly unlikely that costs have not stayed constant or decreased. For 01–02 and 11–12, these total expenditure figures equate to $123 and $197 per person per year respectively, as well as 0.32 and 0.29% of GDP respectively. Although exact relative contributions could not be determined, agriculture accounted for more than 90% of the total economic loss and expenditure in both years (data not presented). Total expenditure in 01–02 relative to the economic cost was 30.9% and was among the highest relative expenditure calculated in the world (Table 1). This figure rose to 38.4% in 11–12.

Discussion

Dealing with invasive species is clearly a significant expense to the Australian economy and environmental budgets. As far as we are aware, the only prior attempt to calculate the holistic cost of economic loss and management expenses for invasive species in Australia is Pimentel et al. (2001). They calculated that in 1998, excluding diseases, invasive species cost Australia $USD 12.33 billion (Pimentel et al. 2001). Here we calculated that in 01–02 the combined cost of economic loss and control was $AUD 9.8 billion. Our figure is lower most likely because Pimentel et al. (2001) made independent calculations for all invasive species within Australia based on many assumptions of the costs of the impacts, rather than relying on the reports that we have here that predominantly detail actual expenditure, but do not include calculated impacts for all species, and also either do not include, or do not provide holistic expenditure for other financial sources such as state-level and local governments, as well as private expenditure. For both Pimentel et al. (2001) and here, many of the data used, are based on conservative minimums, and the calculations made are based on conservative assumptions especially for environmental costs, and therefore the actual costs are likely to be greater. Additionally, our data do not include the multiple hundreds of millions of dollars per year spent on border protection preventing incursions by new species and pathogens. Border protection was not included here because we were unable to obtain the data, and if we had it there would be no clear way to split the relative contribution of the costs for preventing incursions of pathogens which were not included in our analyses. Moreover, our analyses have focused on the cost of exotic species after they have established in Australia rather than preventing further incursions.

Clearly both federal government and total expenditure on invasive species increased over time, with the exception of a more recent decline, both in real terms and as a proportion against all measures (i.e. GDP, per capita, calculated impacts), rising to $3.77 billion in 11–12. But it remains unclear what drove the pattern of increasing expenditure, especially the notable increase post 2008 and then the subsequent decline. Was the increase a response to increasing numbers of invasive species and/or their impacts, new legislation such as the *Environment Protection and Biodiversity Conservation Act 1999* which is the Australian Government's central piece of environmental legislation to protect biodiversity of national and international significance, multiple government biosecurity reviews (Nairn et al. 1996; ECITARC 2004; Beale et al. 2008), or other drivers such as a better informed public calling for more government support, increasing levels of land secured for conservation requiring management action, or that the efficacy of management is improving thereby making expenditure on invasive species management more appealing? We suggest that the answer is likely to be the interplay of all of these factors. Notably, the increase in 2008 funding possibly reflects the election of a new Commonwealth Government in November 2007 and the subsequent shift to the Caring for Country Program in 2008. We are unsure of why funding decreased in 2011 but possibly this reflects Commonwealth Government environmental expenditure priorities changing towards clean energy, coupled with the decline in the Australian economy, rather than money being transferred to sources unaccounted for in this analysis.

An aspect of the expenditure that remains unquantified is the outcome. Are management efforts reducing the influence and extent of invasive species, or are they merely slowing an inevitable spread and rise of impacts? This question has been queried for weed management funded by NHT grants, but it was found that it was not possible to assess program effectiveness due to inadequate reporting requirements, as well as the timing of management programs usually extending far beyond short-term funding arrangements (Martin and van Klinken 2006). Likewise we were unable to perform any such analyses here that quantify management success, value for money, or even progress towards mitigating invasive species impacts in Australia. There is no doubt that there are many localised successes that have mitigated an environmental issue by preventing incursions, successfully controlling an invasive population (Reid and Morin 2008; Palmer et al. 2010), eradicating an invasive species (Oppel et al. 2010; Hoffmann 2011; Tobin et al. 2014), and restoring environments following invasive species removal (Hoffmann 2010; Holsman et al. 2010; Jones 2010), but what about at the regional and national levels? If the latest Australian State of the Environment report is a good indicator, then it is likely that for most species, and hence for invasions in general, that the presence and influence of invasive species is increasing. In its summary, the report states that "pressures, such as those from invasive species, are generally increasing." (SOEC 2011). Unfortunately the rise in the influence of invasive species in not just restricted to Australia, and appears to be the consistent pattern globally (SCBD 2014).

At the global scale, Australia was the jurisdiction with the highest expenditure relative to the estimated economic losses in 11–12 and among the highest is 01–02, but these data should be interpreted with caution because there is such data paucity that very few comparisons could be made. Importantly, most data available for comparison are approximately a decade older than the most recent data presented here, and all data have limited accuracies. In the only estimate of the cost of invasive species to the global economy, Pimentel et al. (2001) estimated that invasive species cost the world USD$1.4 trillion in 1998, which equated to 5% of the global economy. However, this figure included losses due to diseases and pathogens, as well as management costs. Excluding diseases and pathogens, this re-calculates to a global cost of USD$974 billion, equal to 3.1% of global GDP. Interestingly this global percentage figure is much higher than that for Australia in 01–02 (1.37%) and 11–12 (0.92%). It is not clear if this discrepancy is due to Australia having a relatively less problem with invasive species (a very doubtful reality), a relatively stronger economy that is based on industries with less invasive species issues (e.g. mining), fewer invasive species due to stronger biosecurity laws and enforcement, inadequate calculations of the true cost of invasive species to Australia, or the estimates of Pimentel et al. (2001) are too high.

In collating the data for Table 1, it became particularly noticeable that the methods used by different studies to calculate or estimate monetary values varied considerably, often resulting in extremely different outcomes. For example, the most recent attempt to quantify the cost of invasive species to the UK determined the figure to be £1.68 billion (Williams et al. 2010), whereas a report approximately a decade earlier estimated that exotic insects and plant pathogens alone cost the UK £3.08 billion annually (Pimentel 2002). This methodological issue is not easily resolved, because many real values, such as expenditure on pest controllers at a national level divided by taxa, are not able to be sourced, and other non-physical values, such as the value of environmental services or aesthetics, are completely dependent upon opinionated assumptions. Additionally multiple invasive species usually co-occur to produce an impact, or are managed simultaneously, and often the influence of an invasive species is completely unknown. Such high levels of uncertainty result in researchers depending upon "rough guesses" (Pimentel 2002) to estimate costs. Given that there is no simple solution to the problem of how best to determine the cost of invasive species, there can be no doubt that this issue will continue to plague this research arena for quite some time.

Our attempts to collate data for our analyses also highlighted some serious shortcomings globally of the recording and availability of data relating to invasive species, which then greatly hinders analyses that can be conducted. Inadequate data recording was particularly noticeable for Australia's federal funding whereby in most instances we were not even able to obtain information on the focal species of individual projects, thereby preventing even the most basic species-level analysis. These data could be obtained for the oldest data (NHT: 1997–2002), but only if the species name was in the project titles, so any analysis would likely be under-reporting the reality. As such, we cannot even provide a basic analysis showing current relative expenditure on individual species to determine a hierarchy of focus. In turn, this prevents analyses that assess whether funding priorities reflect priorities of need (ie whether species estimated to have the greatest economic cost receive the greatest management and funding).

Given the extent of the issue of invasive species globally (Mack et al. 2000; Pimentel et al. 2001), and that the issue continues to increase, there is a clear need for better quantifications of both cost and expenditure throughout much more of the world to improve awareness and action, as well as to accurately understand the extent of the problem. The ability to provide such information, at least for expenditure, would be greatly enhanced by the use of publicly available databases, such as the LIFE and CORDIS databases recently analysed by Scalera (2010). Within Australia, reporting of project outcomes for the latest federal funding program (Biodiversity fund) has recently been changed to an online system (MERIT) that aims to provide the first long-term holistic reporting system that can be analysed to quantify project outcomes and national goals for invasive species management. The system is housed by the Atlas of Living Australia (http://spatial.ala.org.au). This development represents a great step towards better quantification of management costs and outcomes against invasive species, and is required for two reasons: 1. to determine the effectiveness of programs given the investment that has been made, and, 2. to guide investment in future programs to ensure these are effective. A major criticism of many invasive species management programs is that they are constantly underfunded, however, without a critical evaluation of cost and effectiveness such claims cannot be substantiated.

Overall, invasive species are a significant economic burden in Australia. The cost of managing invasive species is likely to increase due to more species arriving each year, more species already here becoming problematic and therefore requiring management, and because of problematic species continuing to enlarge their distributions. Better quantification of the cost of invasive species is required to help improve public and political awareness of the issue of invasive species, and to assist with decisions of how to respond appropriately to them, particularly regarding cost-effectiveness of management expenditure. Ultimately, the data support Australia's use of stringent biosecurity measures to help reduce the arrival and subsequent establishment of new species (and pathogens).

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