National Biosecurity Research and Development Capability Audit

Intergovernmental Agreement on Biosecurity – Research, Development and Extension Working Group

July 2012

Summary

The National Biosecurity Research and Development (R&D) Capability audit was conducted between January and July 2012. The purpose of the audit was to inform the development of the National Biosecurity Research, Development and Extension (RD&E) Framework (Schedule 8 of the IGAB) in addition to development of the National Animal Biosecurity RD&E Strategy and the National Plant Biosecurity RD&E Strategy under the National Primary Industries RD&E Framework.

The audit provided a snapshot in time of biosecurity R&D capability across the sectors of animal health, plant health, invasive weed species, invasive animal species and invasive marine species. Those conducting generic/cross-sectoral R&D were also in scope. Participants were asked to include all staff working in R&D in the biosecurity sector. The audit was intended to capture capability not only in the more traditional scientific disciplines but also supporting disciplines that apply to biosecurity such as the social sciences.

Responses were received from the Australian government, the Commonwealth Scientific and Industrial Research Organisation (CSIRO) and all state and territory governments (excluding the Australian Capital Territory). The university sector, R&D Corporations (RDCs) and other organisations (e.g. Collaborative Research Centres, Australian Centre of Excellence for Risk Analysis, Animal Health Australia, Plant Health Australia, private R&D providers) were not included in the audit, however it is important to acknowledge their contribution to biosecurity R&D capability. Biosecurity capability information from these organisations will be included in the National Animal Biosecurity RD&E Strategy and the National Plant Biosecurity RD&E Strategy.

The majority of data was analysed cross-sectorally (i.e. data for each sector combined). It is important to note that cross-sectoral trends did not always reflect individual sector trends and therefore conclusions drawn from cross-sectoral data will not necessarily relate to individual sectors. Further information on capability trends for the animal and plant health sectors can be found in the National Animal Biosecurity RD&E Strategy and the National Plant Biosecurity RD&E Strategy.

Some limitations to the capability audit were identified and therefore data summaries should be interpreted with caution.

Human Capability

The audit identified a total of 818.3 full time equivalent (FTE) staff employed in biosecurity R&D across the sectors nationally (Table 1). The greatest capability was in the plant health sector, which contained 362.2 (44%) of the total FTEs in biosecurity R&D (Figure 1). The animal health sector also accounted for a large proportion of the national capability, with 287 (35%) of the total FTEs in biosecurity R&D (Figure 1). The remainder of capability was spread between invasive weed species (70.3 FTEs), invasive animal species (47.8 FTEs), invasive marine species (15.4 FTEs) and generic/cross-sectoral R&D (35.6 FTEs; Figure 1).

Collectively, state and territory government departments were the largest providers of biosecurity R&D, accounting for 58% of the national capability (Table 1 & Figure 2). The remaining 42% of capability was provided by CSIRO and the Australian Government Department of Agriculture, Forestry and Fisheries (DAFF).

The cumulative age distribution across the biosecurity sectors showed that the majority of capability (43%) was aged between 40 and 55 years of age (see Table 2 & Figure 3). A large proportion of capability (38%) were less than 40 years of age and the remaining (19%) were over 55 years of age. The need to replace these 19% into the future highlighted the importance of succession planning and capability building.

The predominant research role in biosecurity R&D was not surprisingly researcher, accounting for 48% of the total FTEs in biosecurity R&D (see Table 4 & Figure 6). A large amount of capability was provided by technical support, accounting for 45% of total FTEs. In contrast, only 3% of capability was provided by postgraduates and 4% of capability was provided by postdoctoral researchers.

FTEs were collected against the national biosecurity R&D priorities and objectives (see Appendix C page 195). The greatest proportion of research effort was against priorities 1 and 2 (see Table 6 & Figure 10). Priority area 1 (minimise the risk of entry, establishment, or spread of pests and diseases) accounted for 50% the total research effort and priority area 2 (eradicate, control or mitigate the impact of established pests and diseases) accounted for 42% the total research effort. In contrast, priorities 3 (understand and quantify the impacts of pests and diseases) and 4 (cost-effectively demonstrate the absence of significant pests and diseases) accounted for only 5% and 3% the total research effort respectively.

Within the priority objectives, the greatest proportion of research effort was against objectives 1B (enhance detection, surveillance and diagnostic systems) and 2B (develop effective and integrated approaches to managing established pests and diseases of national priority; see Table 6 & Figure 11). The least effort was applied to objectives 1C (understand the sociological factors associated with the adoption of risk mitigation measures by stakeholders) and 3B (develop the knowledge base and protocols for managing the invasion risks posed by one sector for others).

Capability existed in a large number of disciplines across the various sectors, demonstrating the complexity of biosecurity R&D. Disciplines were scattered across organisations highlighting the importance of collaboration and coordination of R&D activities between organisations and suggesting there could be difficulties with determining a cross-sectoral relationship model for R&D activities (i.e. identification of major, support, link agencies). Overall, capability in biometrics, geospatial information systems, taxonomy, toxicology and modelling were low across multiple sectors (see Table 8). These disciplines were therefore particularly vulnerable.

In the animal health sector, R&D capability existed in 31 disciplines across all 11 organisations surveyed (Table 8). The majority of R&D was performed by staff with expertise in molecular biology (38.4 FTEs) diagnostics (28.6 FTEs) and immunology (20 FTEs). The lowest capabilities were in mycology (0.3 FTEs), protozoology (0.2 FTEs) and risk analysis (0.1 FTEs).

In the plant health sector, R&D capability existed in 43 disciplines across eight organisations (Table 8). The majority of capability was in the disciplines of entomology (86.6 FTEs), pathology (50.1 FTEs) and mycology (47.9 FTEs). The lowest capabilities were in agronomy, biometrics, microscopy and systematics, each accounting for only 0.1 FTEs.

R&D capability in the invasive weed species sector existed in 15 disciplines across seven organisations (Table 8). The majority of R&D was performed by staff with expertise in agronomy (14.6 FTEs), ecology (12.1 FTEs) and biological control (9.9 FTEs). Disciplines with the lowest capabilities included molecular biology (0.1 FTEs), taxonomy (0.1 FTEs) and population genetics (0.2 FTEs).

In the invasive marine species sector, R&D capability existed in nine disciplines across five organisations (Table 8). The majority of R&D was performed by staff with expertise in surveillance (5.4 FTEs), ecology (4.4 FTEs) and molecular biology (2.3 FTEs). The lowest capabilities were in modelling (0.1 FTEs), oceanography (0.1 FTEs) and taxonomy (0.1 FTEs).

R&D capability in the invasive animal species sector existed in 15 disciplines across six organisations (Table 8). The majority of R&D was performed by staff with expertise in population ecology (12.4 FTEs). Disciplines with the lowest capabilities included taxonomy (0.1 FTEs) and biometrics (0.4 FTEs).

For generic/cross-sectoral R&D, capability existed in 14 disciplines across five organisations (Table 8). The majority of R&D was performed by staff with expertise in economics (9.5 FTEs) and risk analysis (6.9 FTEs). The lowest capabilities were in the disciplines of bioinformatics (0.1 FTEs) and molecular biology (0.1 FTEs).

Investment

A total of $66,411,070 is spent per annum on wages (base wage, not including on-costs) for biosecurity R&D capability across the various sectors (see Table 9 & Figure 14). Approximately 45% of this amount ($29.6 million) was invested in wages for the plant health sector, 36% ($23.8 million) in wages for the animal health sector, 8% ($5.5 million) in wages for invasive weed species, 5% ($3.3 million) in wages for invasive animal species, 5% ($3.2 million) in wages for generic/cross-sectoral R&D and 1% ($0.9 million) in wages for invasive marine species.

External funding to support biosecurity R&D in the year 2011 amounted to $72,365,480 (Table 10). The majority of external funding was spent on generic/cross-sectoral ($28,666,277) and plant health ($28,185,708) R&D (Table 10). The animal health sector received $8,939,207, invasive animal species received $3,679,100, invasive weed species received $2,325,188 and invasive marine species received $570,000 (Table 10). External funding sources varied by sector and included the Australian Government, state and territory governments, Rural Research & Development Corporations (RDC), industry sources, universities, commercial and overseas organisations (see Table 13). Some of the major investors included the Australian Government and Rural RDCs.

External funding was allocated to the national biosecurity R&D priorities and objectives (see Appendix C). The majority of external investment was against priorities 1 and 2 (see Table 11 & Figure 16). Priority area 1 received approximately $35.8 million, accounting for 49.5% of the total external investment and priority area 2 received approximately $34.8 million, accounting for 48% of external investment. In contrast, priority 3 received approximately $1.1 million and priority 4 received approximately $0.6 million, accounting for only 1.5% and 1% the total external investment respectively.

All priority area objectives were externally funded except objective 1C which represented a capability (Table 6) and funding gap (Table 11). The majority of external investment was against objectives 2B (develop effective and integrated approaches to managing established pests and diseases of national priority) and 1D (develop knowledge and strategies to prevent and contain the spread of pests and diseases within national borders; Table 11). The least amount of external funding went towards objectives 2C (understand risk factors that drive emergence of new pests and diseases), 3A (improve understanding of the environmental, economic, and social impacts of pests and diseases and of management activities to control them) and 3B (develop the knowledge base and protocols for managing the invasion risks posed by one sector for others; Table 11). Objective 3B was particularly vulnerable as both capability (Table 6) and external funding (Table 11) against this objective were very low.

Infrastructure

Infrastructure investments for the past five years totalled $769,012,860 (see Table 14). Some of the major investments included capital upgrades to Australian Animal Health Laboratory (AAHL) Geelong, valued at $32 million, development of the Ecosciences Precinct[1] (Dutton Park, Brisbane) and the Health and Food Sciences Precinct[1] (Coopers Plains, Brisbane), valued at $259.5 million and $101.3 million respectively, biosecurity upgrade of Elizabeth Macarthur Agricultural Institute (EMAI) at Menangle, NSW, valued at $57 million and development of the Centre for AgriBioscience[2] (AgriBio), located at La Trobe University's Bundoora campus, valued at $288 million.

Infrastructure investments forecast for the next five years (2012 – 2016) total $20,410,000 (see Table 14). Key investments proposed include the development of the Tropical Biosecurity Laboratory[3] at James Cook University, Townsville, valued at $17 million and continued development of the Central Coast Primary Industries Centre valued at $2 million.

Key national biosecurity R&D infrastructure was also identified by organisations. These are listed in Table 15, with further information in the responses to the qualitative survey (page 92).

Qualitative survey

As part of the capability audit, a qualitative questionnaire was designed to capture expert opinion of researchers and biosecurity policy makers and data not able to be captured quantitatively. Some questions have been included in the organisational summaries (page 103) as they are internally focussed and relate to areas of expertise, international partnerships and future investment direction. The remainder of the survey is reported in the national summary (page 92).

Key vulnerable capabilities common across the sectors were identified and included taxonomists and socio-economic researchers. The ageing pool of expertise and lack of succession planning were also commonly identified by organisations as key vulnerabilities. Common emerging issues that organisations wanted highlighted to decision makers included funding uncertainty, the lack of joint planning and strategy development by researchers and biosecurity managers (government and industry) and the need for a nationally coordinated approach to biosecurity R&D. Potential and/or emerging capabilities that could be applied to all sectors of biosecurity R&D included advances in molecular biology techniques and bioinformatics. Organisations identified that Australia should invest more heavily in cost effective diagnostics and surveillance tools, avoiding incursions and

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[1] Note that this infrastructure was a joint venture between the Queensland Government and CSIRO and is not solely utilised for biosecurity R&D purposes

[2] Note that this infrastructure was a joint venture between the Victorian Government and La Trobe University

[3] Development of this facility has been scrapped

mitigating the impact of new incursions, long term/permanent positions for research staff and coordination of R&D to avoid duplication and encourage national collaborations.

Conclusions

The audit identified significant capability in biosecurity R&D across the sectors of animal health, plant health, invasive weed species, invasive animal species and invasive marine species. Capability was also identified in generic/cross-sectoral R&D. The majority of capability was provided by the larger state government departments (Queensland, New South Wales and Victoria) as well as CSIRO. Audit findings need to be interpreted with caution as a number of limitations were identified (page 17).

The audit identified an ageing population of research staff and low numbers of postgraduate and postdoctoral researchers. This highlighted the need for succession planning and capability building, including stable career paths to attract and retain capability.

Disciplines in biosecurity R&D were many and varied demonstrating the complexity of biosecurity R&D. Vulnerable disciplines were identified for individual sectors. The audit also showed capability was often scattered between multiple organisations demonstrating the importance of coordination of R&D activities and collaboration between R&D providers. A future challenge will be to support a more flexible workforce capability, with flexibility extending across organisations and disciplines, while maintaining a pool of specialist expertise.

Biosecurity R&D is reliant on a large amount of external funding (often referred to as 'soft money') that is not stable and which does not support retention of capability. Reduction or loss of external funding would lead to loss of capability and loss of R&D outputs. To ensure capability and stable career paths into the future there needs to be long term commitment of funds.

Gaps in capability and external investment for the national priorities were identified and in particular included objectives 1C (understand the sociological factors associated with the adoption of risk mitigation measures by stakeholders) and 3B (develop the knowledge base and protocols for managing the invasion risks posed by one sector for others). Objectives 2C (understand risk factors that drive emergence of new pests and diseases), 3A (improve understanding of the environmental, economic, and social impacts of pests and diseases and of management activities to control them) and priority 4 (cost-effectively demonstrate the absence of significant pests and diseases) were also vulnerable. A future challenge will be to balance R&D investment and research effort between the priority areas and objectives.

In the past five years there has been a large investment in infrastructure. However there is a need for adequate capability building and provision of long term career structures so we have the future capacity to utilise this infrastructure. An additional challenge for the future will be to maintain this infrastructure.

Acronyms

AAHL	Australian Animal Health Laboratory
ABC	Approximate Bayesian Computation
ABIN	Australian Biosecurity Information Network
ABRS	Australian Biological Resources Study
ACERA	Australian Centre of Excellence for Risk Analysis
ACIAR	Australian Centre for International Agricultural Research
AgriBio	AgriBioscience
AHL	Animal Health Laboratory
ALA	Atlas of Living Australia
APARP	Australian Pest Animal Research Program
APN	Australian Pacific Network
AQIS	Australian Quarantine and Inspection Service
ARC	Australian Research Council
ARI	Arthur Rylah Institute for Environmental Research
AWI	Australian Wool Innovation
BAC	Bacterial Artificial Chromosome
BCA	Benefit: cost analysis
BIN	Biosecurity Information Network
BioSIRT	Biosecurity Surveillance, Incident, Response and Tracing
BJD	Bovine Johne's disease
BSES	Bureau of Sugar Experiment Stations
Bt	*Bacillus thuringiensis*
BVL	Berrimah Veterinary Laboratory
BYDV	Barley yellow dwarf virus
CCIMPE	Consultative Committee on Introduced Marine Pest Emergencies
CES	CSIRO Ecosystem Sciences
CIBIO	Research Center in Biodiversity and Genetic Resources, Porto, Portugal
CIMMYT	The International Maize and Wheat Improvement Center
CRC	Cooperative Research Centre
CRCNPB	Cooperative Research Centre for National Plant Biosecurity
CSIRO	Commonwealth Scientific and Industrial Research Organisation
CYDV	Cereal yellow dwarf virus
DAFF	Australian Government Department of Agriculture, Forestry and Fisheries
DAFF Qld	Department of Agriculture, Forestry and Fisheries Queensland
DAFWA	Department of Agriculture and Food Western Australia
DEWHA	Department of the Environment, Water, Heritage and the Arts

DFTD	Devil Face Tumour Disease
DISSR	Department of Innovation, Industry, Science and Research
DLRM	Department of Land Resource Management
DNA	Deoxyribonucleic acid
DNRETAS	Department of Natural Resources, Environment, the Arts and Sport
DoR	Department of Resources
DPI NSW	Department of Primary Industries New South Wales
DPI Vic	Department of Primary Industries, Victoria
DPIPWE	Department of Primary Industries, Parks, Water and Environment
DSE	Department of Sustainability and Environment
DSTO	Defence Science and Technology Organisation
EAD	Emergency Animal Disease
EMAI	Elizabeth Macarthur Agricultural Institute
FAO	Food and Agriculture Organization of the United Nations
Fisheries WA	Department of Fisheries Western Australia
FRDC	Fisheries Research & Development Corporation
FTE	Full Time Equivalent
GIS	Geospatial Information Systems
GRDC	Grains Research and Development Corporation
GWRDC	Grape and Wine Research and Development Corporation
HAL	Horticulture Australia Limited
ICARDA	International Center for Agricultural Research in Dry Areas
IGAB	Intergovernmental Agreement on Biosecurity
INRA	French National Institute of Agriculture
IPM	Integrated Pest Management
IPPC	International Plant Protection Commission
IT	Information Technology
LEADDR	Laboratories for Emergency Animal Disease Diagnosis and Response
LIMS	Laboratory Information Management System
MALDI-TOF MS	Matrix-assisted laser desorption/ionisation-time of flight mass spectrometry
MAT	?
MDAP	Monitoring Design Assessment Panel
MDBA	Murray Darling Basin Authority
MISA	Marine Innovation South Australia
MLA	Meat and Livestock Australia
NATA	National Association of Testing Authorities
NBC	National Biosecurity Committee
NCRIS	National Collaborative Research Infrastructure Strategy

NERP	National Environmental Research Program
NHMRC	National Health & Medical Research Council
NIH	National Institutes of Health (United States)
NIWA	National Institute of Water and Atmospheric Research
NLIS	National Livestock Identification Scheme
NSW	New South Wales
NT	Northern Territory
NZ	New Zealand
OIE	World Organisation for Animal Health
OJD	Ovine Johne's disease
OSP	Operational Science Program
PaDIL	Pest and Disease Image Library
PCR	Polymerase Chain Reaction
PIRSA	Department of Primary Industries and Regions South Australia
PISC	Primary Industries Standing Committee
Poultry CRC	Poultry Cooperative Research Centre
PSRF	Premier's Science and Research Fund
Qld	Queensland
R&D	Research and Development
RD&E	Research, Development and Extension
RDC	Research & Development Corporations
RHDV	Rabbit Haemorrhagic Disease Virus
RIRDC	Rural Industries Research & Development Corporation
RNAi	Ribonucleic acid interference
RTPCR	Real Time Polymerase Chain Reaction
SA	South Australia
SA MDB NRM	South Australian Murray Darling Basin Natural Resource Management Board
SAGIT	South Australian Grain Industry Trust
SARDI	South Australian Research and Development Institute
SARS	Severe Acute Respiratory Syndrome
SEWPaC	Department of Sustainability, Environment, Water, Population and Communities
SRM	Sustainable Resource Management
TNRM	Territory National Resources Management
UK	United Kingdom
USA	United States of America
USDA	United States Department of Agriculture
Vic	Victoria
WA	Western Australia

WHS	Workplace Health & Safety
YTK	Yellowtail Kingfish

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1. Introduction and Scope

Biosecurity is the management of risks to the economy, the environment, and the community, of pests and diseases entering, emerging, establishing or spreading.

Australia remains free from many pests and diseases that affect agriculture, natural and built environments, and people in other parts of the world. This favourable biosecurity status confers significant economic, environmental and community benefits.

Maintaining and improving Australia's biosecurity status is the responsibility of all Australians. Investing in a strong, multi-layered system to maintain a favourable biosecurity status will benefit Australia.

Biosecurity management is a complex task and Australia's biosecurity system will need to respond to increasing challenges that are changing its risk profile, including climate change, globalisation, population growth and changing demographics and land use.

In January 2012, all Australian governments committed to the Intergovernmental Agreement on Biosecurity (IGAB), an agreement that will strengthen the working partnership between the Australian and state and territory governments[4]. It will improve the national biosecurity system by identifying the roles and responsibilities of governments and outlining the priority areas for collaboration to improve the national biosecurity system. Biosecurity research, development and extension (RD&E) is one of these priority areas.

The National Biosecurity Research, Development and Extension (RD&E) Framework (Schedule 8 of the IGAB) is being developed with the objective of achieving 'a robust and integrated national biosecurity research and development capability and infrastructure to collaboratively support the management of biosecurity risks' (Appendix A). An IGAB R&D Working Group is managing the development of the National Biosecurity RD&E Framework (the Framework). This Working Group is chaired by the Australian Government Department of Agriculture, Fisheries and Forestry (DAFF) and includes representatives from some state and territory departments of primary industries, Commonwealth Scientific and Industrial Research Organisation (CSIRO), Animal Health Australia, Plant Health Australia and the New Zealand Ministry for Primary Industries.

To inform the development of the Framework, biosecurity stakeholders agreed to undertake a comprehensive cross-sectoral biosecurity R&D capability audit to capture information on Australia's capability and investment in biosecurity R&D. This information will be used by Australian governments to decide where individual governments will perform a leadership role in biosecurity R&D where there is a major priority for the relevant government, and a support role and effective linkages in research areas where they are not leaders.

The audit will additionally inform the development of the National Animal Biosecurity RD&E Strategy and the National Plant Biosecurity RD&E Strategy under the National Primary Industries RD&E Framework. The principles of this Framework are intended to guide efforts to enhance the collaboration, coordination, efficiency and effectiveness of RD&E efforts nationally. In addition, continued and coordinated investment in RD&E helps to provide Australia's primary industries with the necessary capability (people, infrastructure and information) to improve their productivity, sustainability and competitiveness.

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[4] http://www.coag.gov.au/intergov_agreements/docs/intergovernmental_agreement_biosecurity.rtf

A Statement of Intent (June 2009)[5] was drafted by Primary Industries Standing Committee (PISC) to capture the intention of the Parties to work collectively and collaboratively to develop and implement the National Primary Industries RD&E Framework, and the underpinning national sector and cross sector strategies. The National Animal Biosecurity RD&E Strategy and the National Plant Biosecurity RD&E Strategy are two such cross-sectoral strategies.

The capability audit was designed to cover all biosecurity sectors including plant health, animal health, invasive marine species, invasive animal species and invasive weed species (Appendix B). It collected information on R&D only. Collection of information on extension capability will be performed at a later date. Endemic, exotic, and emerging infectious pests and diseases were included in the scope of the audit.

The audit was sent to the Australian Government, state and territory governments, universities, and other suspected sources of biosecurity R&D capability (e.g. museums, aquariums, botanic gardens). Organisations with capability in biosecurity R&D were asked to complete the audit and provide a coordinated response from their organisation. Responses were received from the Australian Government, government departments of primary industries and CSIRO. Environment agencies, universities and other organisations were more difficult to engage. It is important however to note that there is capability in these other organisations, including the private sector.

At a workshop on 23 May 2012, the IGAB RD&E Working Group agreed that a report to NBC should focus on cross-sectoral issues arising out of data collected from government agencies and CSIRO. Animal Health Australia has collected data from universities as part of the development of the National Animal Biosecurity RD&E Strategy and Plant Health Australia is continuing to collect data from universities as part of the development of the National Plant Biosecurity RD&E Strategy. These strategies will form components of the National Biosecurity RD&E Framework – Schedule 8 of the IGAB.

The audit was designed in 4 parts. Information was collected between January and June 2012.

Part A collected data on human capability against nationally agreed biosecurity R&D priorities. When reading this report, it may be useful to print out the National Biosecurity R&D Priorities and associated objectives (Appendix C) to assist in interpretation of the data analysis. Information was collected on full time equivalents (FTE) in biosecurity R&D, research role, age, base salary, discipline, research area of interest, primary biosecurity R&D priority area and whether the research was focussed on endemic, exotic, emerging or invasive pest or disease.

Part B of the audit requested information from organisations about the location and value of infrastructure investments in the last 5 years (2007-2011) and the next 5 years (2012-2016), and about capital investment in equipment in the last 2 years (2010-2011). Organisations were also asked to identify key national biosecurity R&D infrastructure.

In Part C, organisations were requested to provide information on levels and sources of external investment for the year 2011 broken down by biosecurity R&D sector and national biosecurity R&D priority area.

[5] http://www.daff.gov.au/__data/assets/pdf_file/0020/1450631/rde-statement-intent.pdf

A qualitative questionnaire was designed for Part D of the audit to attempt to capture expert opinion of researchers and biosecurity policy makers and data not able to be captured quantitatively. Some questions have been included in the organisational summaries as they are internally focussed and relate to areas of expertise, international partnerships and future investment direction. The remainder of the survey is reported in the national summary and captures information on key national biosecurity R&D infrastructure, key capability that is vulnerable or at risk, emerging issues and emerging and potential capabilities for biosecurity R&D and opinion on where Australia should invest more heavily into the future.

This report contains a summary of analysis performed on data collected from organisations engaged in biosecurity R&D who participated in the National Biosecurity R&D Capability Audit. Results are presented by sector (where relevant) and by organisation. The national summary provides aggregation of the organisational data to get an indication of national capability and level of investment in biosecurity R&D capability and infrastructure, and to allow for capture of expert opinion on key national R&D resources and emerging issues and potential opportunities.

2. Limitations of the capability audit

There were a number of recognised limitations to the capability audit including:

- By its nature, the capability audit is "a snapshot in time" of staffing levels and the activities being undertaken. Data for the capability audit was collected during the period February – July 2012 and since that time, some jurisdictions have restructured their departments responsible for biosecurity and this may have impacted on their capability and capacity for biosecurity R&D.
- Different interpretations of how to record FTEs despite detailed guidelines. Hence organisations may have over or underestimated FTEs in biosecurity R&D.
- Different approaches and interpretations of scope and definitions despite detailed guidelines. An example is inclusion of those working purely in diagnostic service delivery rather than diagnostic R&D.
- Capability can be found in organisations that were not audited or did not provide a response to the audit. For example, environmental departments (state/territory and Australian Government), museums, botanic gardens, private research providers and universities all contain capability in biosecurity R&D.
- Capability may be able to apply expertise across multiple disciplines, pests and/or diseases despite only being able to identify one of each through the audit tool.

3. National Summary

3.1. Human capability

Comparison between sectors

Nationally, a total of 818.3 Full time equivalent (FTE) staff were employed in biosecurity R&D during the period (January 2012 - June 2012) in which the audit was conducted (see Table 1 & Figure 1). The greatest capability was in the plant health sector, which contained 362.2 (44%) of the total FTEs in biosecurity R&D. The animal health sector also accounted for a large proportion of the national capability, with 287 FTEs (35%). The remainder of capability was spread between invasive weed species (70.3 FTEs; 9%), invasive animal species (47.8 FTEs; 6%), invasive marine species (15.4 FTEs; 2%) and the generic/cross-sectoral category (35.6 FTEs; 4%). State government departments conducted the majority of biosecurity R&D nationally, accounting for 58% of capability, with the remaining 42% of capability provided by CSIRO and DAFF.

Comparison between organisations (cross-sectoral)

Assessing the cross-sectoral capability by organisation, CSIRO was found to conduct the greatest proportion of biosecurity R&D nationally, accounting for 249.9 (31%) of the total FTEs in biosecurity R&D (see Table 1 & Figure 2). The Department of Agriculture, Forestry and Fisheries Queensland (DAFF Qld) also had a large capability, containing 167.2 (20%) of the total FTEs nationally. The Department of Primary Industries, Victoria (DPI Vic; 103.9 FTEs), the Department of Primary Industries New South Wales (DPI NSW; 100.3 FTEs) and DAFF[6] (95.7 FTEs) had similar capabilities, representing 13%, 12% and 12% of the total national FTEs respectively. The Department of Agriculture and Food Western Australia (DAFWA; 39.3 FTEs) and the Department of Primary Industries and Regions South Australia (PIRSA; 33.4 FTEs) also contained similar capabilities, representing 5% and 4% of FTEs respectively. The Department of Primary Industries, Parks, Water and Environment, Tasmania (DPIPWE; 7.3 FTEs), the Department of Resources, Northern Territory (DoR; 7.7 FTEs), the Department of Fisheries Western Australia (Fisheries WA; 6.6 FTEs) and the Arthur Rylah Institute for Environmental Research, Victoria (ARI Vic; 6.9 FTEs) all contained approximately 1% of FTEs, representing the lowest cross-sectoral capabilities in biosecurity R&D.

Comparison between organisations (by sector)

All organisations surveyed conducted some biosecurity R&D in animal health (see Table 1 & Figure 2). The organisation with the greatest capability in this sector was CSIRO, with 159.7 (56%) of the animal health FTEs. In comparison, ARI Vic (0.3 FTEs), PIRSA (0.5 FTEs) and Fisheries WA (0.8 FTEs) conducted the least biosecurity R&D in animal health, accounting for only 0.1%, 0.2% and 0.3% of total FTEs in animal health respectively.

All organisations conducted biosecurity R&D in plant health, except ARI, Vic, DPIPWE and as expected, Fisheries WA (see Table 1 & Figure 2). DAFF Qld had the greatest capability in this sector, containing 104.3 (29%) of the plant health FTEs nationally. In contrast the

[6] DAFF does not undertake 'bench R&D'. DAFF plant and animal scientists undertake risk assessments and develop policies on animal, plant and public health. They research and analyse existing and new science to reach conclusions, practical outcomes and develop policy.

organisation with the lowest capability in plant health was DoR, containing only 3.5 (1%) of the total FTEs in the plant health sector.

CSIRO, DAFF, DAFF Qld, DPI NSW, DPI Vic, ARI Vic and PIRSA were the only organisations conducting biosecurity R&D in the invasive weed species sector (see Table 1 & Figure 2). Similar to the plant health sector, DAFF Qld had the greatest capability, with 19.7 (28%) of the FTEs nationally. DPI NSW also contained a high capability, with 17.8 FTEs, representing 26% of the total FTEs for invasive weeds. In comparison ARI Vic conducted only 1% (0.4 FTEs) of the biosecurity R&D on weeds nationally.

DAFF, DPI NSW, DPI Vic, ARI Vic, PIRSA and Fisheries WA were the only organisations surveyed to conduct biosecurity R&D in the invasive marine species sector (see Table 1 & Figure 2). PIRSA and Fisheries WA carried out the majority of biosecurity R&D in this sector, accounting for 40% (6.1 FTEs) and 38% (5.8 FTEs) of FTEs respectively. ARI Vic conducted the least R&D in invasive marine species, with only 1% (0.1 FTEs) of FTEs nationally.

Biosecurity R&D for the invasive animal species sector was conducted by all organisations surveyed except DPI Vic, Fisheries WA, DPIPWE and DoR (see Table 1 & Figure 2). CSIRO (10.3 FTEs), DPI NSW (9.5 FTEs) and DAFF Qld (9.2 FTEs) all conducted a similar proportion the biosecurity R&D in this sector, representing 22%, 20% and 19% of the total FTEs for invasive animal species respectively. The lowest capability was held by DAFF, with 1 FTE, representing 2% of total FTEs for invasive animal species.

For generic/cross-sectoral R&D, DAFF, CSIRO, DAFF Qld, DPI Vic and DoR were the only organisations to assign biosecurity R&D to this category (see Table 1 & Figure 2). DAFF had the greatest capability in this sector, with 24.1 (68%) of the generic/cross-sectoral FTEs. This was partly due to the large capability of DAFF in the disciplines of economics and risk analysis (see Table 8). DoR contained 0.3 FTEs, representing only 1% of the national capability in this sector.

For further information on capability in the plant and animal health sectors, refer to the National Plant Biosecurity RD&E Strategy and the National Animal Biosecurity RD&E Strategy. For further information on each organisation's capability spread between the sectors, refer to the organisational summaries (page 103).

Table 1. Full time equivalent (FTE) staff in biosecurity R&D

Sector	DAFF[7]	CSIRO	DAFF Qld	DPI NSW	DPI Vic	ARI Vic	PIRSA	DAFWA	Fisheries WA	DPIPWE	DoR	Total
Animal health	14.2	159.7	32.2	31.4	26.1	0.3	0.5	10.5	0.8	7.3	4.0	**287.0**
Plant health	54.4	58.8	104.3	40.0	61.2	0	18.8	21.4	0	0	3.5	**362.2**
Invasive weed species	1.0	13.8	19.7	17.8	13.9	0.4	3.8	0	0	0	0	**70.3**
Invasive marine species	1.0	0	0	1.7	0.7	0.1	6.1	0	5.8	0	0	**15.4**
Invasive animal species	1.0	10.3	9.2	9.5	0	6.1	4.3	7.4	0	0	0	**47.8**
Generic/Cross-sectoral	24.1	7.3	1.9	0	2.1	0	0	0	0	0	0.3	**35.6**
Total	**95.7**	**249.9**	**167.2**	**100.3**	**103.9**	**6.9**	**33.4**	**39.3**	**6.6**	**7.3**	**7.7**	**818.3**

[7] DAFF does not undertake 'bench R&D'. DAFF plant and animal scientists undertake risk assessments and develop policies on animal, plant and public health. They research and analyse existing and new science to reach conclusions, practical outcomes and develop policy.

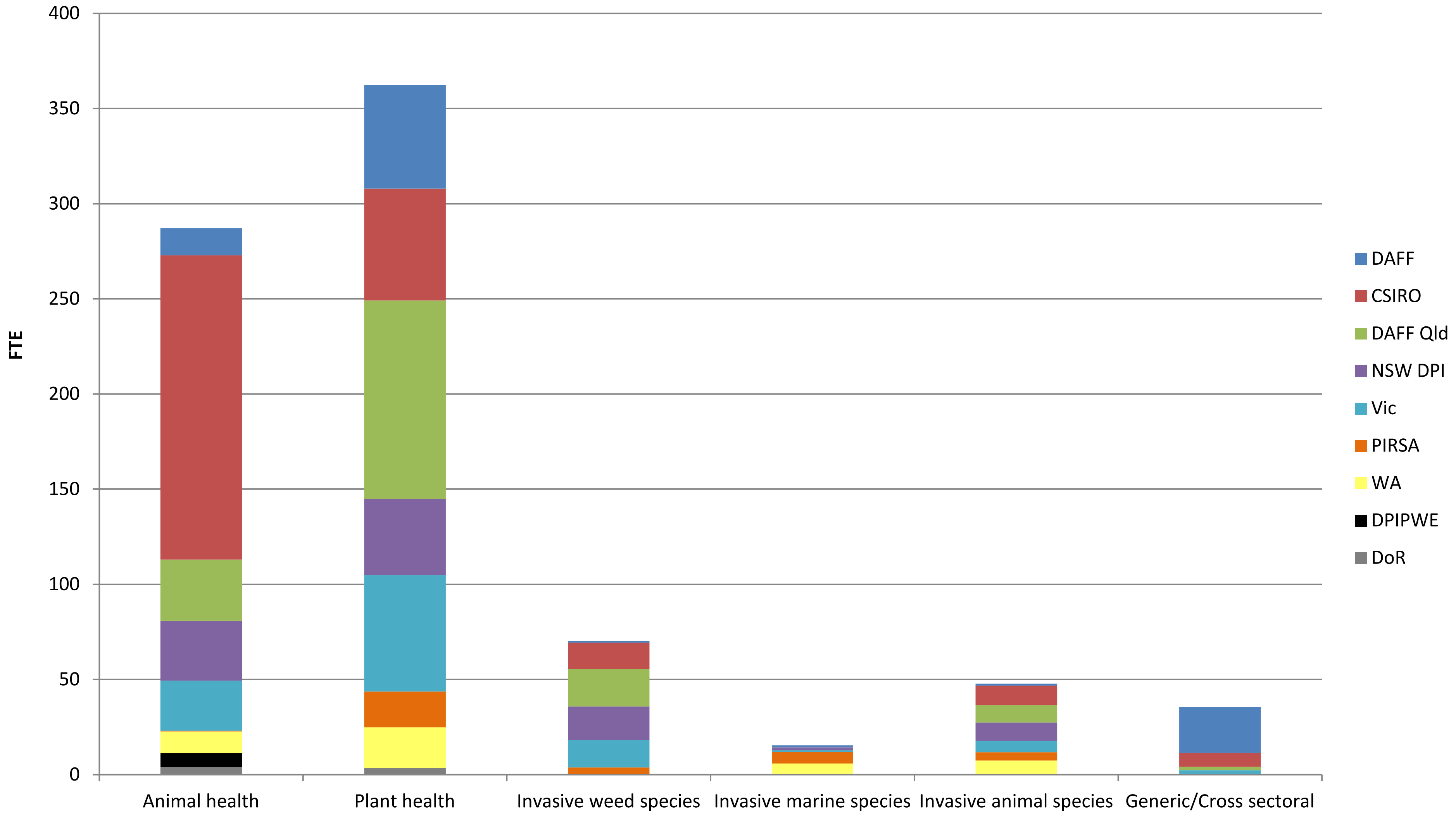

Figure 1. Full time equivalent (FTE) staff in biosecurity R&D by sector and organisation[8]

[8] Data for Vic includes DPI Vic and ARI and data for WA includes DAFWA and Department of Fisheries

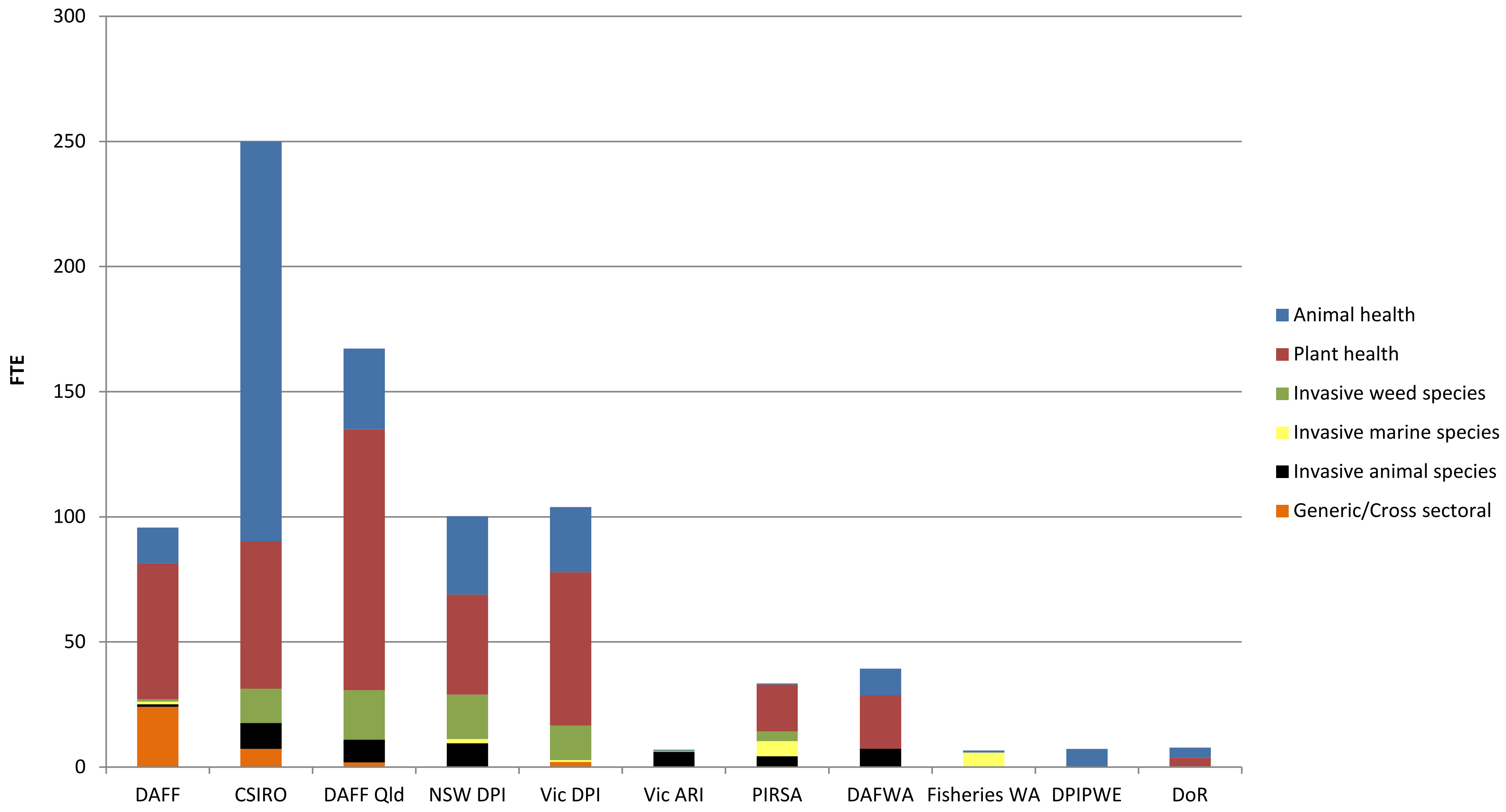

Figure 2. Full time equivalent (FTE) staff in biosecurity R&D by organisation and sector[9]

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[9] DAFF does not undertake 'bench R&D'. DAFF plant and animal scientists undertake risk assessments and develop policies on animal, plant and public health. They research and analyse existing and new science to reach conclusions, practical outcomes and develop policy.

3.1.1. Age

The cumulative age distribution across the biosecurity sectors showed that the majority of capability (43%) was aged between 40 and 55 years of age (Table 2 & Figure 3). A large proportion of capability (38%) was less than 40 years of age and the remaining 19% were over 55 years of age. The need to replace these 19% into the future highlights the importance of succession planning.

Comparison by sector

Looking at the sectors individually, a similar trend was observed for animal health, with capability spread fairly even between those less than 40 years of age and those between 40 and 55 years of age (Table 2 & Figure 4). These age groups represented 39% and 43% of the animal health capability respectively, with the remaining 19% over 55 years of age.

Similarly, for the plant health sector, the majority (45%) of capability was between 40 and 55 years of age (Table 2 & Figure 4). A large proportion of capability, representing 35%, were less than 40 years of age and the remaining 20% were over 55 years of age.

The invasive weed species sector showed a similar age spread, with the majority of capability, representing 42% of FTEs, between 40 and 55 years of age (Table 2 & Figure 4). A large proportion of capability, representing 34%, were less than 40 years of age and 24% were over 55. Therefore almost a quarter of the capability is ageing and will need to be replaced into the future.

The invasive marine species sector showed a different trend. The majority of capability, representing 88% of FTEs, was less than 40 years of age and the remaining 12% were between 40 and 55 years of age. There was no capability over 55 years of age (Table 2 & Figure 4). This suggests difficulty in retaining capability beyond the age of 40.

For the invasive animal species sector, 47% of capability was less than 40 years of age, 40% were between 40 and 55 years of age and the remaining 13% were over 55 years of age (Table 2 & Figure 4).

The generic/cross sectoral group showed a similar age distribution to the national spread, with large proportions of capability less than 40 years of age (43%) and between 40 and 55 years of age (40%; see Table 2 & Figure 4). The remaining 17% were over 55 years of age.

Key issues

- Ageing population of research capability. Hence there is a need for better succession planning and capability building to replace ageing researchers. This was particularly the case for animal health, plant health, invasive weed species and generic/cross sectoral R&D.
- Low retention of capability in the invasive marine species sector to beyond the age of 40, and therefore a need for succession planning to address this.

Table 2. Proportion[10] of full time equivalent (FTE) staff in biosecurity R&D by age bracket and sector

Sector	Age bracket			
	<40	40-55	>55	Total
Animal health	13.2	14.7	6.4	**34.4**
Plant health	15.7	20.5	9.1	**45.3**
Invasive weed species	2.8	3.6	2.0	**8.4**
Invasive marine species	1.5	0.2	0.0	**1.7**
Invasive animal species	2.8	2.4	0.8	**5.9**
Generic/Cross-sectoral	1.8	1.7	0.7	**4.3**
Total	**37.9**	**43.0**	**19.1**	**100.0**

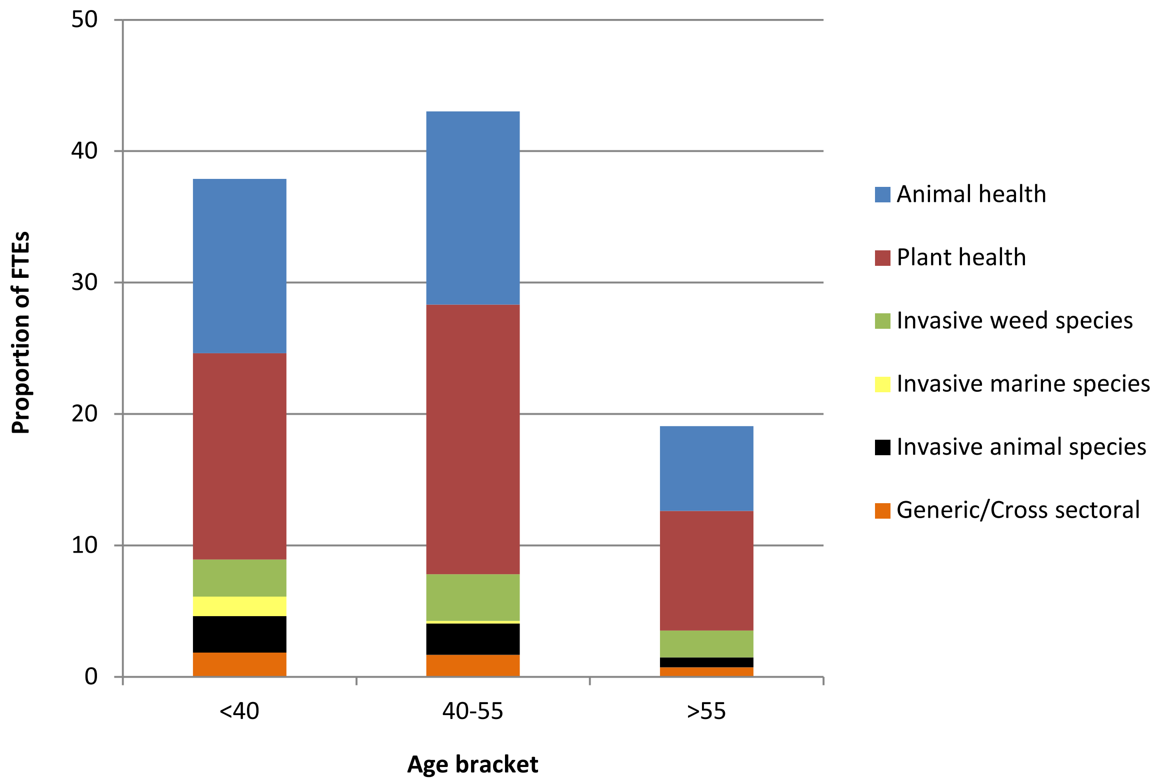

Figure 3. Proportion of full time equivalent (FTE) staff in biosecurity R&D by age bracket and sector

[10] Data for age is reported as proportion of total FTEs as the data returned from some organisations was incomplete

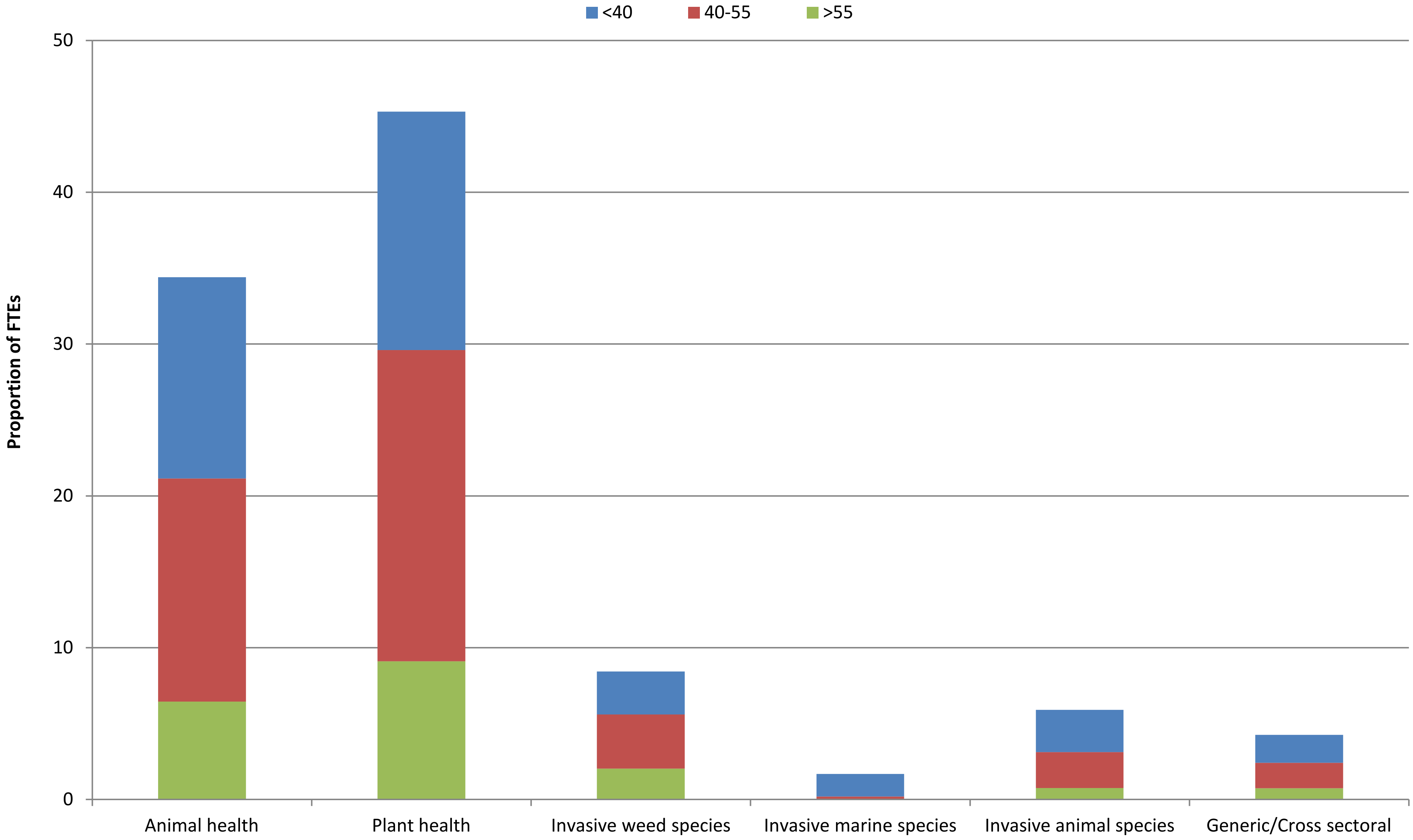

Figure 4. Proportion of full time equivalent (FTE) staff in biosecurity R&D by age bracket and sector

Comparison by organisation

Assessing the age distribution by organisation, DAFF, CSIRO, DAFF Qld, PIRSA and DPIPWE all had comparable distributions of capability between the age groups (see Table 3 & Figure 5). Capability was fairly evenly spread between those less than 40 years of age and those between 40 and 55 years of age. The lowest proportion of capability in these organisations was over 55 years of age. However for DAFF and DAFF Qld, these proportions were still quite high, with 19% of DAFF capability over 55 and 24% of DAFF Qld capability over 55. In contrast, for CSIRO, DPIPWE and PIRSA, relatively low proportions of capability were over 55 (14% for CSIRO, 11% for DPIPWE and 5% for PIRSA).

Approximately half of the total capability in DPI NSW, DPI Vic and DAFWA was between 40 and 55 years of age (see Table 3 & Figure 5). The majority of the remaining capability in DPI NSW and DPI Vic was less than 40 years of age (approximately 30%). Despite this, a relatively high proportion of capability was over 55 (22% for DPI NSW and 24% for DPI Vic). For DAFWA, the majority of remaining capability (28%) was over 55 years of age, with only 22% of capability less than 40 years of age. Therefore, in particular for DAFWA, this represents a high proportion of capability that will need to be replaced into the future.

Similar to most other organisations, the majority of capability (40%) in DoR was between 40 and 55 years of age (see Table 3 & Figure 5). The remaining capability was evenly spread between those less than 40 years of age (30%) and those over 55 years of age (30%). Again, this represented a high proportion of ageing capability.

For ARI Vic, the majority of researchers (61%) were less than 40 years of age. The remaining 39% were between 40 and 55 years of age and there was no capability over 55 years of age (Table 3 & Figure 5). The age distribution in Fisheries WA was similar, with the majority of capability (88%) less than 40 years of age, a low proportion of capability (12%) between 40 and 55 and no researchers over 55 years of age (Table 3 & Figure 5). These organisations appear to have difficulty in retaining capability beyond 40 years of age.

For further information on the age distribution on an organisational basis refer to the organisational summaries (page 103).

Table 3. Proportion of full time equivalent (FTE) staff in biosecurity R&D by age bracket and organisation

Organisation	Age bracket			
	<40	**40-55**	**>55**	**Total**
DAFF	4.3	4.6	2.1	**11.0**
CSIRO	13.7	13.3	4.5	**31.5**
DAFF Qld	8.0	8.1	5.0	**21.1**
DPI NSW	3.7	6.0	2.8	**12.5**
DPI Vic	3.1	5.3	2.7	**11.1**
ARI Vic	0.5	0.3	0	**0.9**
PIRSA	2.0	2.1	0.2	**4.2**
DAFWA	1.1	2.5	1.4	**5.0**
Fisheries WA	0.7	0.1	0	**0.8**
DPIPWE	0.4	0.4	0.1	**0.9**
DoR	0.3	0.4	0.3	**1.0**
Total	**37.9**	**43.0**	**19.1**	**100.0**

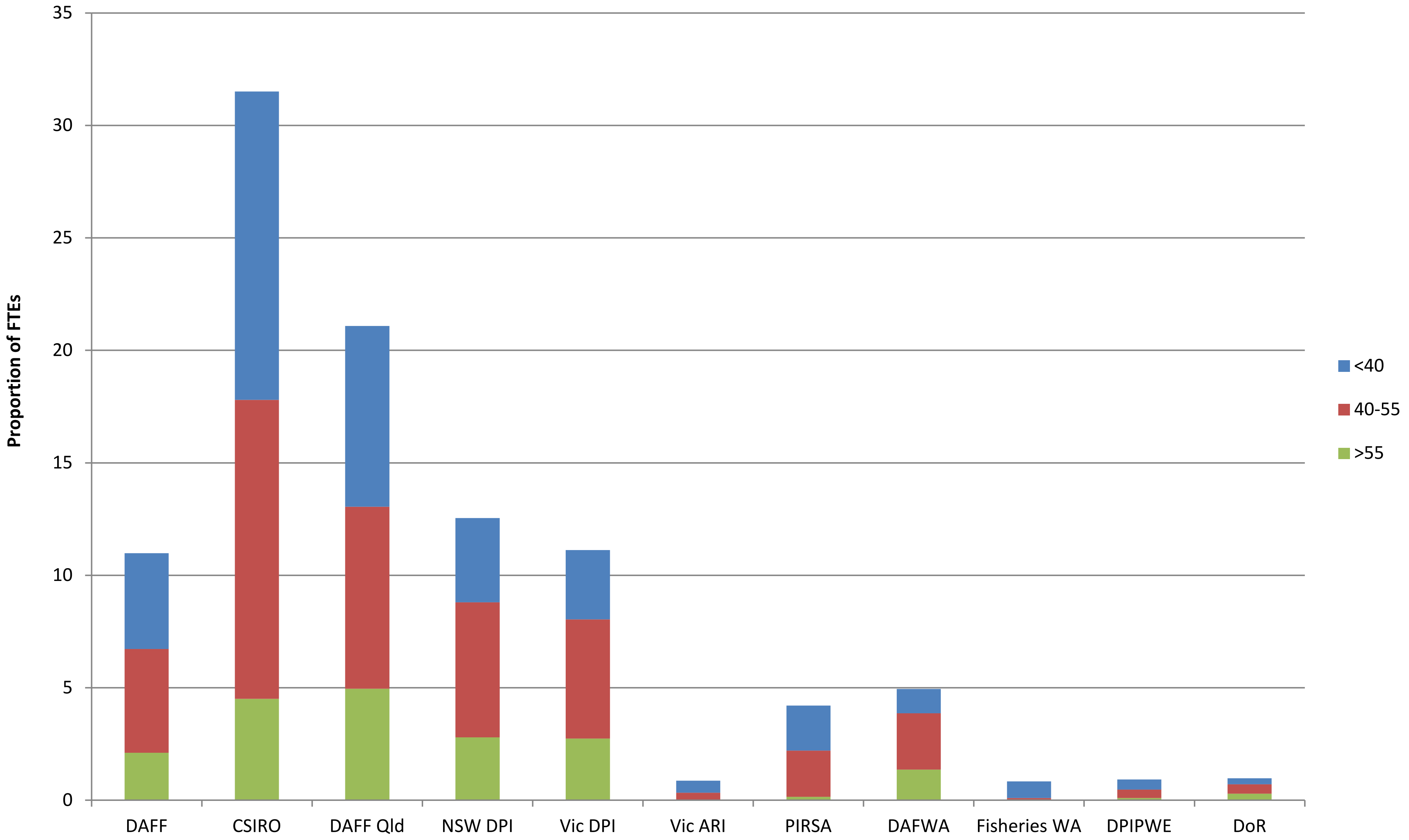

Figure 5. Proportion of full time equivalent (FTE) staff in biosecurity R&D by age bracket and organisation

3.1.2. Research role

The predominant research role in biosecurity R&D across the sectors was not surprisingly researcher, accounting for 393 (48%) of the total FTEs in biosecurity R&D (see Table 4 & Figure 6). A large amount of capability (370 FTEs) was provided by technical support, accounting for 45% of total FTEs. In contrast, only 3% (24 FTEs) of capability was provided by postgraduates and 4% (30 FTEs) of capability was provided by postdoctoral researchers. This again highlights the need for succession planning and capability building as postgraduates and postdoctoral researchers represent the future pool from which researchers (and in some cases technicians) will be drawn from.

Comparison by sector

For the animal health sector, the majority of biosecurity R&D was carried out by technicians, accounting for 146.5 (51%) of the total FTEs in animal health (see Table 4 & Figure 7). Researchers provided 38% of the capability (110 FTEs), while postgraduates (20 FTEs) and postdoctoral researchers (11 FTEs) accounted for 7% and 4% of capability respectively. The lower percentage of postdoctoral researchers compared to postgraduates suggests not all postgraduates are continuing on their research career through postdoctoral work. Some postgraduates (e.g. Honours or Masters Graduates) could be moving into technical roles or they could possibly be moving out of animal health R&D.

For plant health, an equal amount of capability (175 FTEs) was provided by researchers and technicians (see Table 4 & Figure 7). This represented 48% of FTEs each. In contrast, postgraduates (2.2 FTEs) accounted for only 1% of capability in plant health and postdoctoral researchers (10 FTEs) represented 3% of capability. In particular, the low percentage of postgraduates suggests an urgent need to attract postgraduates to biosecurity R&D related disciplines and highlights the importance of succession planning and capability building for future plant health R&D.

The invasive weed species sector showed a different profile to plant health, with the majority of R&D (44 FTEs; 63%) provided by researchers (see Table 4 & Figure 7). Technicians accounted for 35% (25 FTEs) of capability, while postgraduates and postdoctoral researchers represented only 0.5% (0.3 FTEs) and 2% (1.3 FTEs) of capability respectively. These findings again highlight the need for future succession planning.

The invasive marine species sector showed a similar trend to invasive weed species, with the predominant R&D role being researcher, accounting for 69% (10 FTEs) of capability (see Table 4 & Figure 7). Only 24% (3.5 FTEs) of capability was provided by technicians and 7% (1 FTE) by postdoctoral researchers. No R&D was conducted by postgraduates, suggesting a recent lack of postgraduate recruitment in this sector.

For the invasive animal species sector, the majority of R&D was carried out by researchers, accounting for 56% (26 FTEs) of the capability (see Table 4 & Figures 6 & 7). Technicians provided 31% (14 FTEs) of the capability, postgraduates provided 0.2% (0.1 FTEs) and postdoctoral researchers accounted for 13% (6.1 FTEs) of capability. The proportion of capability provided by postdoctoral researchers was higher than any other sector, however there were very few postgraduates, suggesting that, similar to the invasive marine species sector, there has been recent difficulty in postgraduate recruitment in this sector.

For generic/cross-sectoral R&D the predominant research role was researcher, accounting for 28 (80%) of the total FTEs for this sector (see Table 4 & Figures 6 & 7). Only 16% (5.6 FTEs) of capability was provided by technical support, reflecting that much of the generic/cross-sectoral R&D was desk rather than laboratory based, for example, for disciplines such as economics, risk analysis and information technology (see Table 8). A small proportion of R&D was conducted by postgraduates (3%, 1 FTE) and postdoctoral researchers (2%, 0.7 FTEs)

Key issues

- Low capability provided by postgraduate and postdoctoral researchers. Hence there is a need to attract young technicians and researchers into biosecurity R&D and provide better succession planning to ensure these researchers are retained into the future.
- Long term career structures that ensure we attract and keep the capability for research will help address this issue.

Table 4. Proportion[11] of full time equivalent (FTE) staff in biosecurity R&D by research role and sector

Sector	Research role				
	Researcher	Technician	Postgraduate	Postdoctoral researcher	Total
Animal health	13.4	17.9	2.4	1.3	**35.2**
Plant health	21.4	21.5	0.3	1.2	**44.4**
Invasive weed species	5.4	3.0	0.0	0.2	**8.6**
Invasive marine species	1.2	0.4	0.0	0.1	**1.8**
Invasive animal species	3.2	1.8	0.0	0.7	**5.7**
Generic/Cross-sectoral	3.5	0.7	0.1	0.1	**4.4**
Total	**48.2**	**45.3**	**2.9**	**3.7**	**100.0**

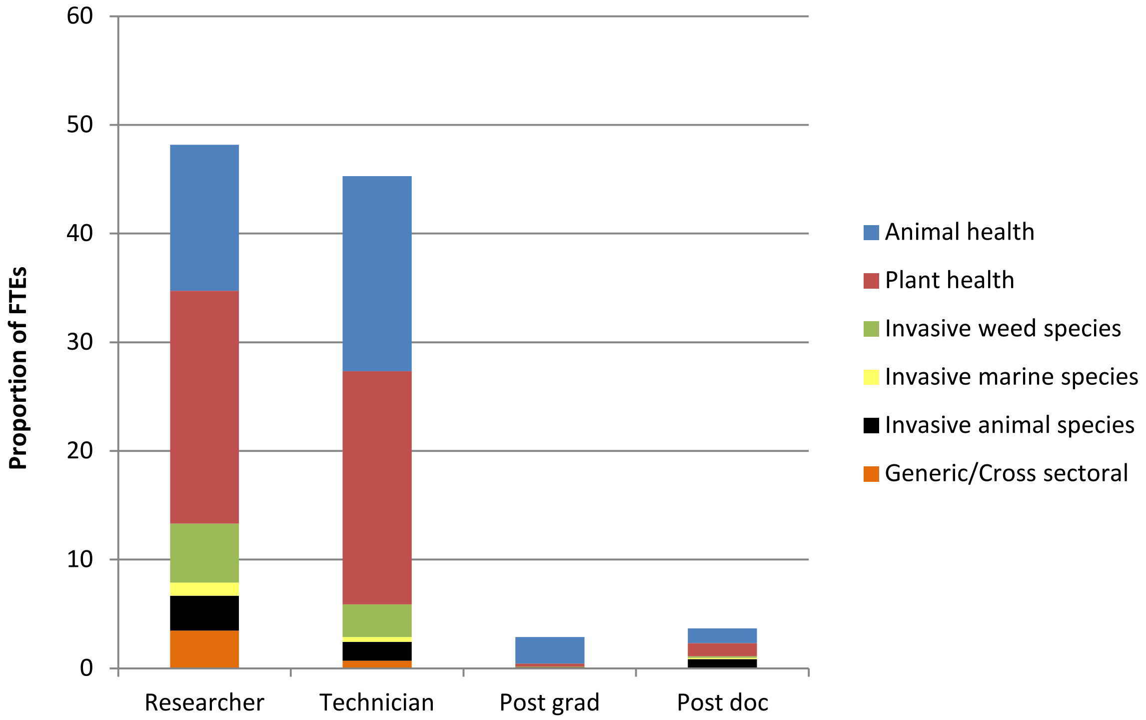

Figure 6. Proportion of full time equivalent (FTE) staff in biosecurity R&D by research role and sector

[11] Data for research role is reported as proportion of total FTEs as the data returned from some organisations was incomplete

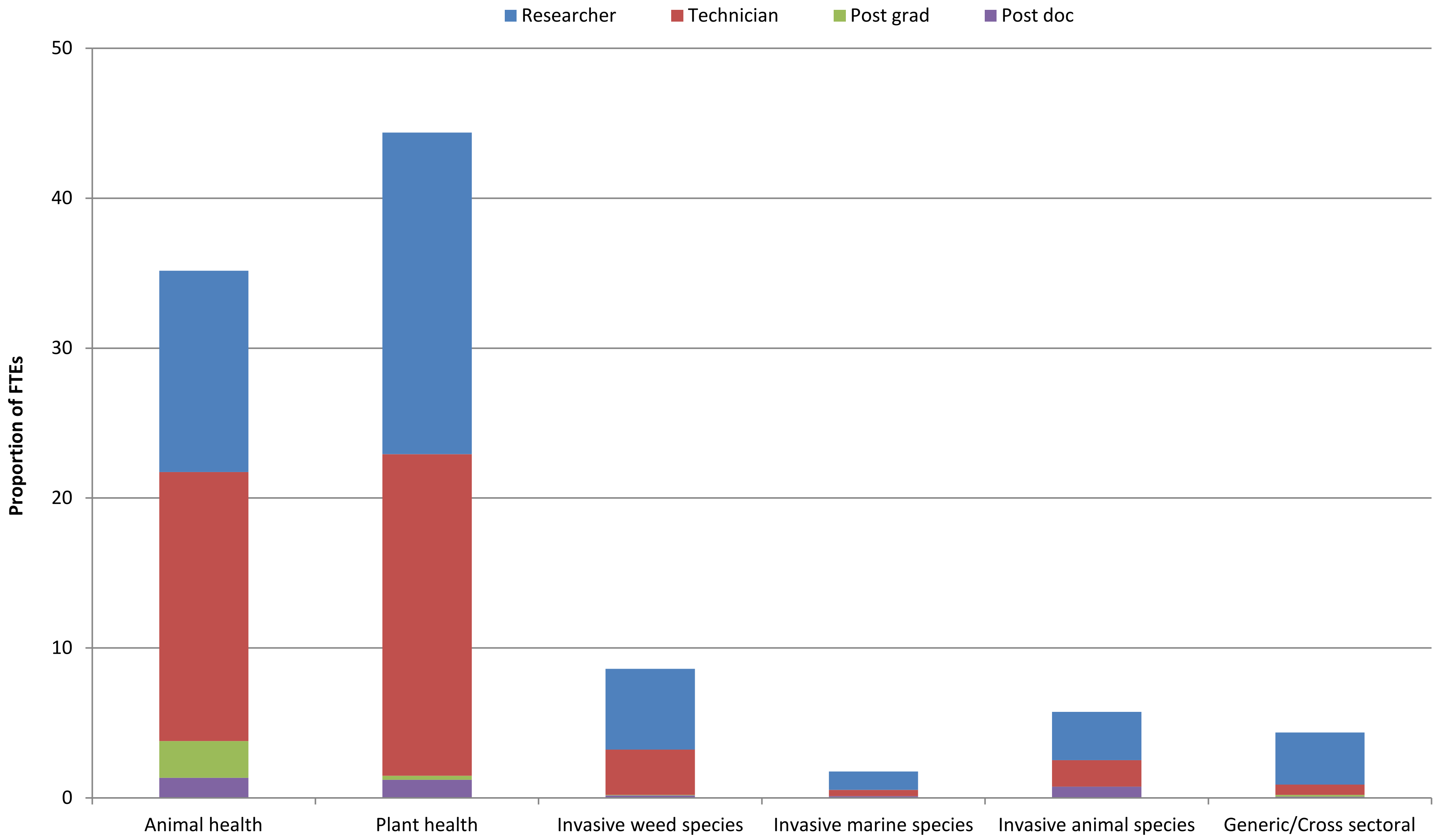

Figure 7. Proportion of full time equivalent (FTE) staff in biosecurity R&D by research role and sector

Comparison by organisation

Comparing the distribution of research roles by organisation, DAFF Qld, CSIRO and DPI Vic had the greatest researcher capability nationally (see Table 5 & Figure 8). For DAFF Qld, researchers accounted for 90.7 FTEs, representing 23% of biosecurity researchers. CSIRO and DPI Vic contained 21% (83.8 FTEs) and 19.2% (75.3 FTEs) of researcher capability.

DAFF Qld and CSIRO also had the greatest technical capability nationally (see Table 5 & Figure 8). For CSIRO, technicians accounted for 119.7 FTEs, representing 32% of technical capability and for DAFF Qld, 75.4 FTEs were allocated to technicians, representing 20% of technical capability. DAFF also contained a high technical capability, accounting for 68.7 (18%) of the total FTEs for technicians nationally. However, where the majority of technical support in CSIRO, DAFF Qld and other organisations audited is laboratory based, technicians in DAFF do not undertake 'bench R&D'. Rather, DAFF plant and animal scientists undertake risk assessments and develop policies on animal, plant and public health. They research and analyse existing and new science to reach conclusions, practical outcomes and develop policy.

Seven organisations contained postgraduate research capability, including DAFF, CSIRO, DAFF Qld, DPI Vic, PIRSA, DAFWA and DPIPWE (see Table 5 and Figure 8). CSIRO had the greatest postgraduate capability, with 19.4 FTEs, representing 82% of postgraduates nationally. For all other organisations, postgraduates represented a very low proportion (8% or less) of postgraduate capability.

Only four organisations contained postdoctoral researchers, including CSIRO, DAFF Qld, DPI NSW and Fisheries WA (see Table 5 and Figure 8). CSIRO had the greatest postdoctoral researcher capability, with 27 FTEs, representing 90% of postdoctoral researchers nationally. In contrast DAFF Qld, DPI NSW and Fisheries WA accounted for less than 4% of postdoctoral researcher capability nationally.

Comparing the distribution of research roles within organisations, researcher was the predominant role in DAFF Qld, DPI NSW, DPI Vic, ARI Vic, PIRSA, Fisheries WA, DPIPWE and DoR (see Table 5 & Figure 9). A large proportion of capability in these organisations was also provided by technical support. DAFWA showed a similar spread of research capability, however the proportion of R&D provided by researchers and technicians was almost equivalent. For the majority of these organisations, very little (<3%), or no R&D capability was provided by postgraduates or postdoctoral researchers. Fisheries WA however was an exception, with 15% of capability provided by postdoctoral researchers.

The staff profile in DAFF and CSIRO differed to other organisations, with the predominant research role being technician (see Table 5 & Figure 9). For DAFF, technicians made up 75% of the capability and researchers represented 24% of capability. Only 0.6% of capability was provided by postgraduates and there were no postdoctoral researchers. It is important to note that much of the R&D carried out by DAFF technicians and researchers is desk based research, for example, in the disciplines of economics and risk analysis (see Table 8). CSIRO was the organisation with the greatest proportion of research capability provided by postgraduates and postdoctoral researchers (see Table 5 & Figure 9). These represented 8% and 11% of CSIRO capability respectively. Technicians provided 48% of capability and researchers accounted for 34% of capability.

For further details on research roles in each organisation, refer to the organisational summaries (page 103).

Table 5. Proportion of full time equivalent (FTE) staff in biosecurity R&D by research role and organisation

Organisation	Research role				
	Researcher	Technician	Postgraduate	Postdoctoral researcher	Total
DAFF	2.7	8.4	0.1	0.0	**11.2**
CSIRO	10.3	14.7	2.4	3.3	**30.7**
DAFF Qld	11.1	9.3	0.0	0.1	**20.5**
DPI NSW	6.8	5.5	0.0	0.1	**12.3**
DPI Vic	9.2	3.3	0.2	0.0	**12.8**
ARI Vic	0.8	0.0	0.0	0.0	**0.8**
PIRSA	3.0	1.0	0.1	0.0	**4.1**
DAFWA	2.3	2.4	0.1	0.0	**4.8**
Fisheries WA	0.5	0.1	0.0	0.1	**0.8**
DPIPWE	0.6	0.3	0.0	0.0	**0.9**
DoR	0.7	0.3	0.0	0.0	**1.0**
Total	**48.1**	**45.3**	**2.9**	**3.7**	**100.0**

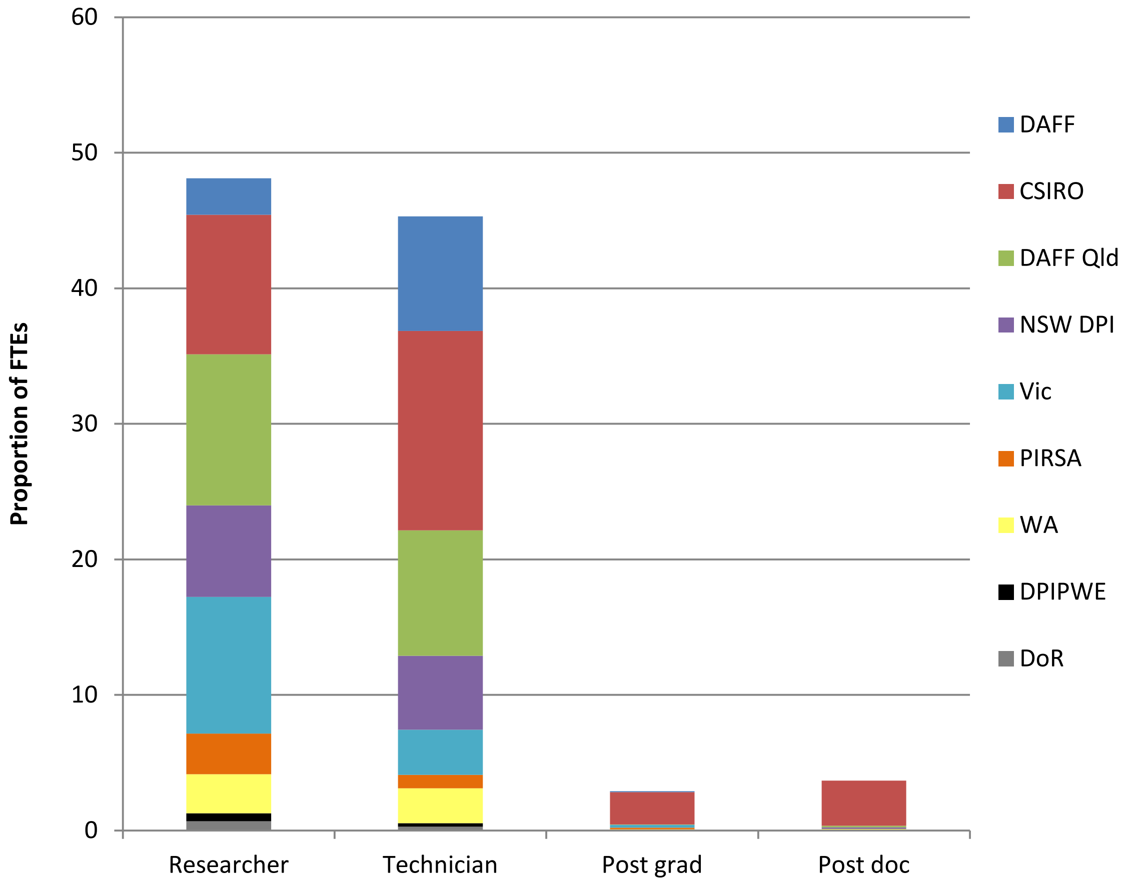

Figure 8. Proportion of full time equivalent (FTE) staff in biosecurity R&D by research role and organisation[12]

[12] Data for Vic includes DPI Vic and ARI and data for WA includes DAFWA and Department of Fisheries

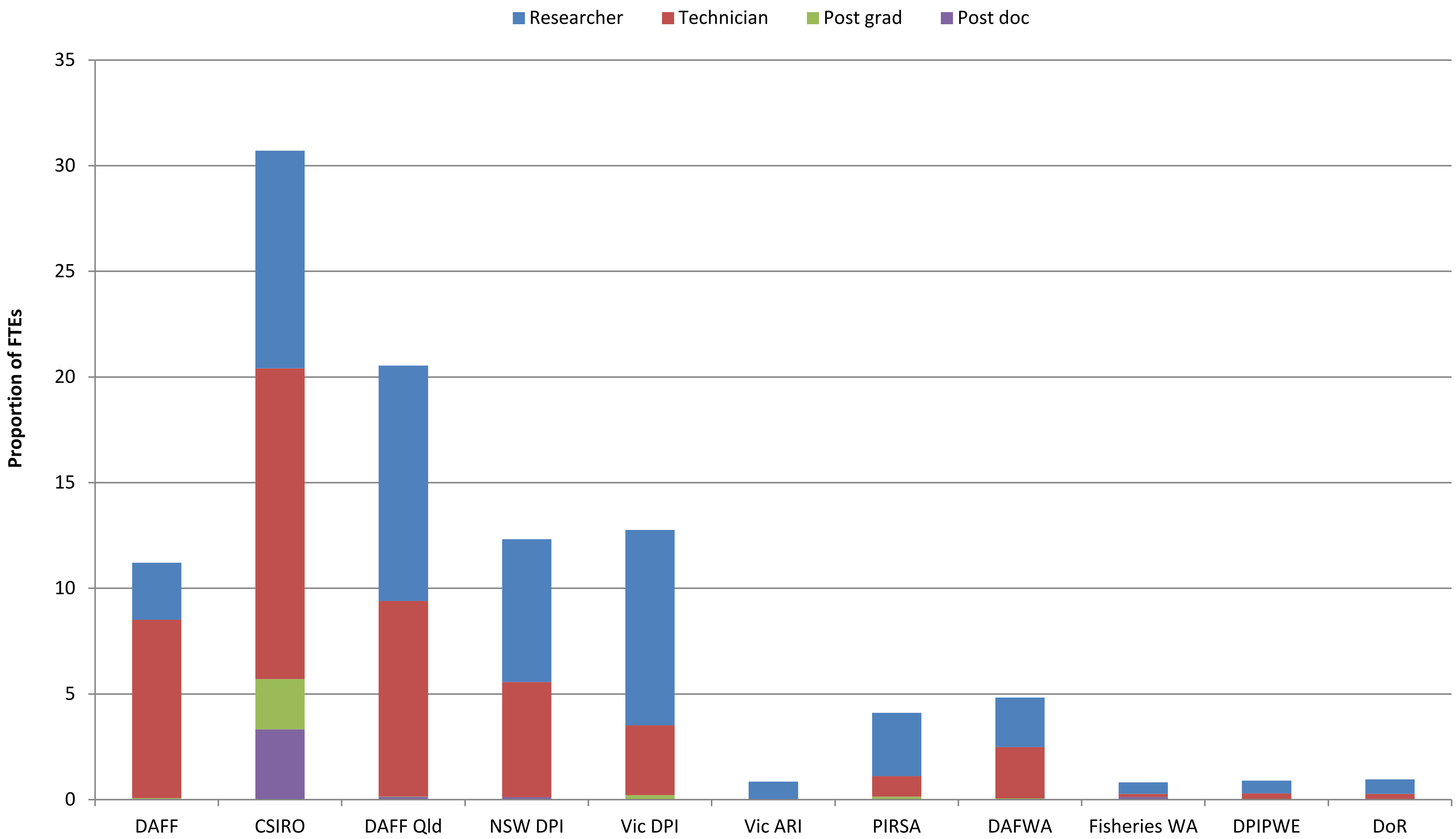

Figure 9. Proportion of full time equivalent (FTE) staff in biosecurity R&D by research role and organisation

3.1.3. Priority area

FTEs were collected against the national biosecurity R&D priorities (see Appendix C). Comparing the priorities cross-sectorally, the greatest proportion of research effort was against priorities 1 and 2 (Table 6 & Figure 10). Priority area 1 accounted for 50% the total research effort, and priority area 2 accounted for 42% the total research effort. In contrast, priorities 3 and 4 accounted for only 5% and 3% the total research effort respectively (Table 6 & Figure 10).

Comparing the R&D effort between objectives, the greatest proportion of research effort was against objectives 1B and 2B, which represented 19% and 21% of FTEs respectively (Table 6 & Figure 11). Objectives 1A and 2D also accounted for a large proportion of research effort, representing 13% and 12% of FTEs respectively. Remaining objectives accounted for less than 10% research effort, with 8% against objective 1D, 9% against 1E, 6% against 2A, 4% against 2C and 3A, and only 1% against both 1C and 3B (Table 6 & Figure 11).

Comparison by sector

All sectors conducted R&D against each of the four priority areas (Table 6 & Figure 10). Comparing the sectors, animal health conducted the greatest proportion of R&D against priorities 1 (37%) and 4 (49%), plant health conducted the majority of R&D (56%) against priority 2, and R&D that falls in to the generic/cross-sectoral category accounted for the majority of FTEs (30%) against priority 3 (Table 6 & Figure 10).

All sectors conducted R&D against each of the 11 objectives, except 1C, in which the invasive marine species sector conducted no R&D against (Table 6 & Figure 11). Comparing between sectors, plant health conducted the greatest proportion of R&D against objectives 1A (42%), 1C (64%), 1D (48%), 1E (45%), 2B (57%), 2C (49%), 2D (66%) and 3B (52%). Animal health conducted the majority of R&D against objective 1B (73%) and 2A (46%). R&D that falls in to the generic/cross-sectoral category accounted for the greatest proportion of FTEs (36%) against objective 3A.

For the animal health sector, the majority of research effort was against priority 1, accounting for 67% of FTEs (Table 6 & Figure 10). The least amount of research effort was against priority 3, accounting for only 2% of FTEs for this sector. Animal health R&D was conducted against all of the objectives, with the greatest proportion of research effort (39%) against objective 1B (Table 6 & Figure 11). Research effort was spread fairly evenly between objectives 1A, 1D, 1E, 2A, 2B and 2D, which each account for approximately 10% of FTEs. Less than 5% of FTEs were against objectives 2C and 3A, however the objectives with the least research effort were 3B, representing only 0.4% of FTEs and 1C accounting for only 0.03% of the total FTEs for animal health.

The majority of research effort in plant health was against priority 2, accounting for 53% of FTEs (Table 6 & Figure 10). The least amount of research effort was against priority 4, with 2% of FTEs. Plant health R&D was conducted against all of the objectives, with the greatest proportion of research effort against objectives 2B (26%) and 2D (17%; Table 6 & Figure 11). Research effort was spread fairly evenly between objectives 1A, 1B, 1D and 1E which all accounted for approximately 10% of FTEs. Objectives 2A and 2C both represented 5% of total R&D effort, while the objectives with the least research effort were 1C, 3A and 3B, each accounting for less than 2% of FTEs.

The majority of research effort in invasive weed species was against priority 2, accounting for 62% of FTEs for that sector (Table 6 & Figure 10). The least amount of research effort was against priority 4, representing only 1% of FTEs. Invasive weed species R&D was conducted against all the objectives, with the greatest proportion of research effort against objectives 2B (46%) and 1A (24%; Table 6 & Figure 11). Approximately 10% of FTEs were against objective 2D, and 4% against objectives 1E, 2C and 3A. Research effort was also evenly spread between objectives 1D, 2A and 3B, which each representing 2% of FTEs. Objectives with the least research effort included 1B and 1C, each accounting for less than 1% of total FTEs for this sector.

The majority of research effort in the invasive marine species sector was against priority 1, representing 53% of FTEs (Table 6 & Figure 10). The least amount of research effort was against priority 4, representing only 3% of FTEs. Research in this sector was conducted against all objectives except 1C, with the greatest proportion of R&D (21%) against objective 1B (Table 6 & Figure 11). Research effort was spread evenly between objectives 1A, 1D, 1E, 2B, and 3A, each representing approximately 10% of FTEs. Objectives 2A and 2D each accounted for 8% of FTEs, and the objectives with the least research effort were 2C and 3B, accounting for 4% and 3% of FTEs respectively.

The majority of research effort in the invasive animal species sector was against priority 1, accounting for 48% of FTEs (Table 6 & Figure 10). Similar to most other sectors, the least amount of research effort was against priority 4, representing 5% of FTEs. The invasive animal species sector conducted R&D against all the objectives, with the greatest proportion of FTEs against objectives 1A (34%) and 2B (20%; Table 6 & Figure 11). Research effort was spread fairly evenly between objectives 1E, 2D and 3A, each representing approximately 8% of FTEs. Objectives 1D and 2A each represented approximately 5% of FTEs and objective 2C accounted for 4% of FTEs. Objectives with the least research effort included 1B, 1C and 3B, each accounting for only 1% of FTEs.

For R&D that is considered generic/cross-sectoral, the majority of research effort was against priority 1, representing 44% of total FTEs for this sector (Table 6 & Figure 10). The least amount of research effort was against priority 4, representing only 4% of FTEs. Research in this sector was conducted against all objectives, with the greatest proportion of FTEs against objectives 1A (22%) and 3A (34%; Table 6 & Figure 11). A large majority of FTEs (12%) were against objective 1E and research effort was fairly evenly spread between objectives 1D, 2C and 2D, each representing approximately 6% of FTEs. Objectives 1C, 2A and 2B each accounted for 3% of FTEs and the objectives with the least research effort included 1B and 3B, each accounting for less than 1% of total FTEs for this sector.

Key issues

- Relatively low amount of R&D conducted against priorities 3 and 4 and objectives 1C and 3B.

Table 6. Full time equivalent (FTE) staff in biosecurity R&D by national R&D priority/objective by sector

Sector	National biosecurity R&D priorities and objectives											
	1A	**1B**	**1C**	**1D**	**1E**	**2A**	**2B**	**2C**	**2D**	**3A**	**3B**	**4**	**Total**
Animal health	21.3	113.2	0.1	28.0	28.7	20.7	28.0	11.0	19.3	5.2	1.0	10.5	**287.0**
Plant health	45.3	36.8	4.0	32.8	33.2	18.0	95.5	17.4	62.7	6.6	3.8	6.0	**362.2**
Invasive weed species	16.6	0.2	0.7	1.4	2.9	1.3	32.0	2.6	6.8	2.7	1.4	0.9	**69.4**
Invasive marine species	1.6	3.0	0	1.6	1.4	1.2	1.4	0.6	1.2	1.6	0.5	0.4	**14.4**
Invasive animal species	16.0	0.6	0.4	2.4	3.1	2.9	9.5	1.7	3.4	4.2	0.4	2.4	**46.8**
Generic/Cross-sectoral	7.4	0.7	1.1	1.8	4.0	1.1	1.1	2.0	2.1	11.4	0.3	1.2	**34.1**
Total	**108.2**	**154.4**	**6.3**	**67.9**	**73.3**	**45.1**	**167.5**	**35.3**	**95.5**	**31.7**	**7.3**	**21.4**	**813.8**

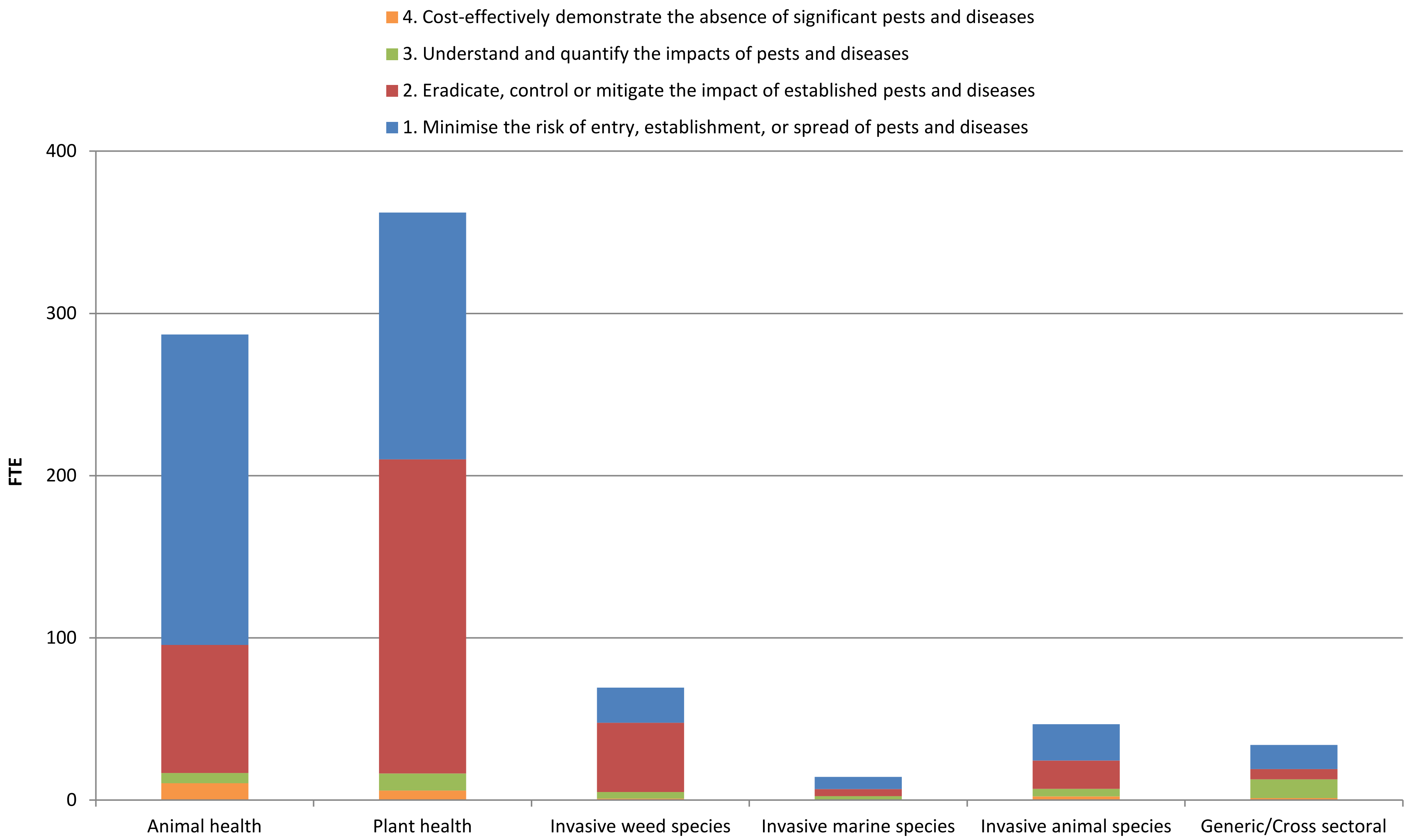

Figure 10. Full time equivalent (FTE) staff in biosecurity R&D by national biosecurity R&D priority by sector

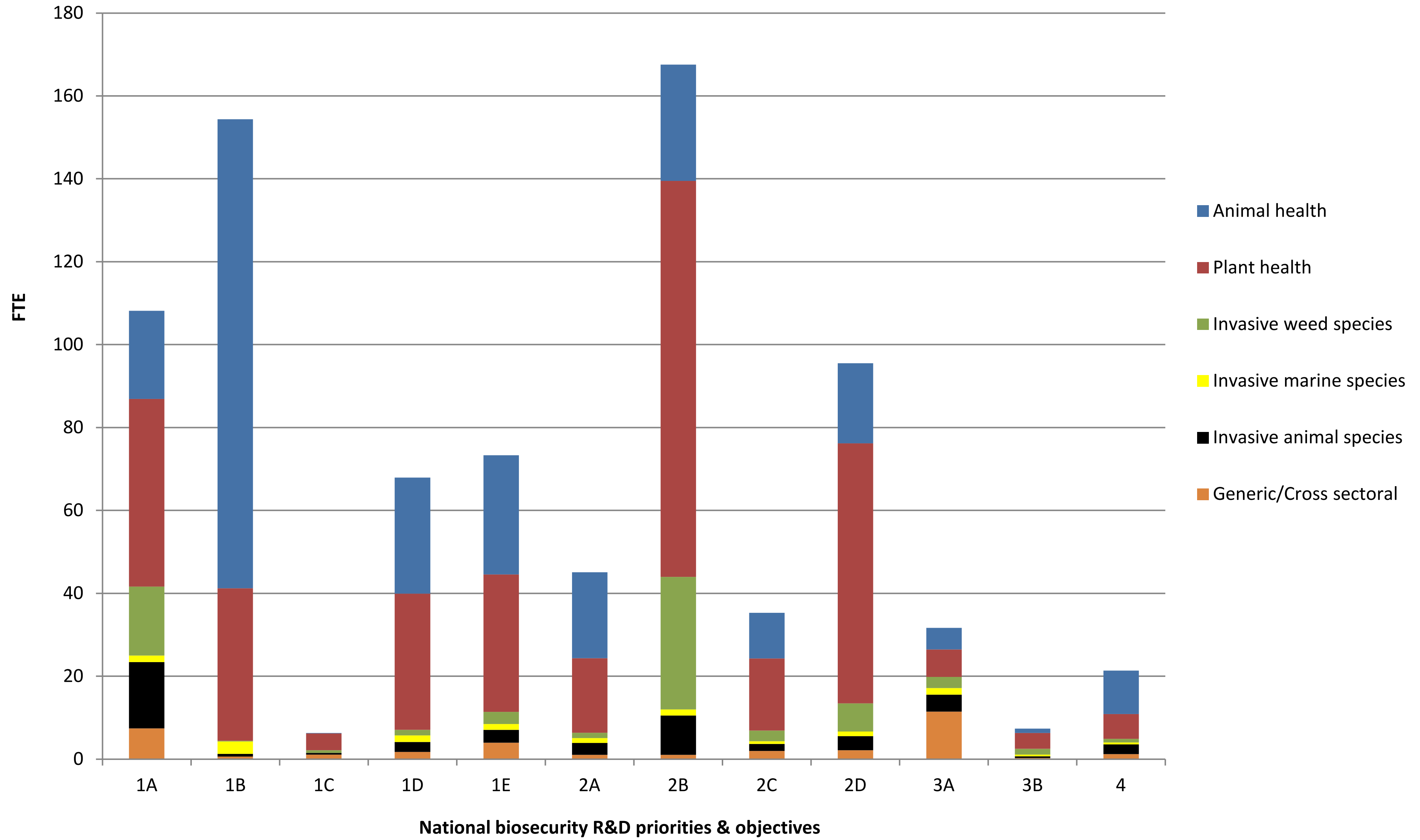

Figure 11. Full time equivalent (FTE) staff in biosecurity R&D by national biosecurity R&D priority/objective by sector

Comparison by organisation

Comparing priority area by organisation, all organisations surveyed conducted R&D against priority area 1, with CSIRO conducting the greatest proportion of R&D (44%) against this priority (Table 7 & Figure 12). In contrast ARI Vic only accounted for 0.5% of research effort against this priority. All organisations except DPIPWE conducted R&D against priority 2, with DAFF Qld responsible for the majority of R&D (41%). In contrast, Fisheries WA were responsible for only 0.1% the research effort against this priority. All organisations except ARI Vic and DPIPWE conducted research against priority 3, with DAFF conducting the majority of R&D (41%). In contrast, DoR accounted for only 0.3% the research effort against this priority. All organisations except DPIPWE and DoR spent some R&D effort against priority 4, and the organisation conducting the greatest proportion of R&D against this priority (30%) was DPI NSW (Table 7 & Figure 12). The organisation conducting the least amount of R&D against this priority was ARI Vic, accounting for less than 1% research effort.

Comparing objectives, all organisations surveyed conducted R&D against objective 1A, with CSIRO conducting the majority of R&D (37%) against this objective (Table 7 & Figure 13). ARI Vic and Fisheries WA were responsible for the least research effort against this priority, accounting for only 0.4% of FTEs.

Similarly, all organisations conducted R&D against objective 1B, with CSIRO conducting the majority of R&D (48%) against this objective (Table 7 & Figure 13). DPI Vic also conducted a large proportion of the R&D against objective 1B, accounting for 24% of FTEs. ARI Vic were responsible for the least amount of research effort against this objective, accounting for only 0.1% of FTEs.

Objective 1C was not covered by all organisations, with only DAFF, CSIRO, DPI NSW, DPI Vic and DAFWA conducting R&D against this objective (Table 7 & Figure 13). CSIRO conducted the greatest proportion of R&D against 1C, representing 63% of FTEs. In contrast, DPI Vic only conducted 2% of the R&D against this objective.

All organisations conducted R&D against objective 1D, except DPIPWE. CSIRO conducted the majority of research against this objective, accounting for 51% of FTEs (Table 7 & Figure 13). DAFF and DPI NSW also accounted for a large proportion of the R&D against this objective, with 17% and 14% of FTEs respectively. In contrast, DPI Vic and DoR were responsible for the least R&D against objective 1D, representing less than half a percent of FTEs against this objective.

All organisations except DoR conducted R&D against objective 1E, with CSIRO conducting the majority of R&D (37%) against this objective (Table 7 & Figure 13). DPI NSW were also responsible for a large proportion of the R&D against objective 1E, accounting for 21% of FTEs. Vic DPI and PIRSA conducted the least R&D, accounting for less than 1% of FTEs against this objective.

All organisations except Fisheries WA, DPIPWE and DoR conducted R&D against objective 2A, with the majority of R&D (55%) conducted by DAFF Qld (Table 7 & Figure 13). In contrast, DPI NSW and PIRSA conducted the least R&D against this objective, accounting for only 2% of FTEs.

All organisations except DPIPWE conducted R&D against objective 2B. As with objective 2A, DAFF Qld conducted the majority of R&D against objective 2B, accounting for 30% of FTEs (Table 7 & Figure 13). A large proportion of R&D was also conducted by DPI Vic (22%) and

CSIRO (19%). In contrast, Fisheries WA were responsible for only 0.2% of R&D against this objective.

All organisations conducted R&D against objective 2C except Fisheries WA, DPIPWE and DoR (Table 7 & Figure 13). The majority of R&D against objective 2C was conducted by CSIRO (36%), DAFF Qld (21%) and DAFF (15%). Only 1% of R&D was conducted by ARI Vic.

All organisations conducted R&D against objective 2D except Fisheries WA and DPIPWE (Table 7 & Figure 13). CSIRO were responsible for the greatest proportion of R&D against this objective, accounting for 51% of FTEs. In contrast, DoR accounted for less than 1% of the R&D against this objective.

All organisations conducted R&D against objective 3A, except ARI Vic and DPIPWE. DAFF carried out the majority of R&D against this objective, accounting for 49% of FTEs (Table 7 & Figure 13). In contrast, DoR were responsible for the least amount of R&D against this objective, accounting for only 0.2% of FTEs.

Objective 3B was covered by fewer organisations, with only DAFF, CSIRO, DPI NSW, DPI Vic, PIRSA, DAFWA and DoR conducting R&D against this objective (Table 7 & Figure 13). CSIRO conducted the majority of research (41%) against objective 3B, with DPI NSW (20%) also conducting a large proportion of the R&D. In contrast, DoR conducted only 1% of the R&D against objective 3B.

All organisations conducted R&D against priority 4, except DPIPWE and DoR. The majority of R&D against this priority was accounted for by DPI NSW, representing 30% of FTEs (Table 7 & Figure 13). CSIRO and DAFF Qld were also responsible for a large proportion of the R&D, with 19% and 15% of FTEs respectively. In contrast, ARI Vic and Fisheries WA both conducted approximately 1% of the R&D against priority area 4.

For further detail on coverage of priority areas and objectives by individual organisations, refer to the organisational summaries (page 103).

Table 7. Full time equivalent (FTE) staff in biosecurity R&D by national R&D priority/objective by organisation

Organisation	National biosecurity R&D priorities and objectives											
	1A	1B	1C	1D	1E	2A	2B	2C	2D	3A	3B	4
DAFF	10.2	5.9	1.6	14.5	14.7	5.1	4.3	6.2	5.0	19.6	2.0	2.2
CSIRO[13]	36.6	78.1	8.5	44.2	34.1	8.0	35.5	15.4	30.2	9.5	5.0	5.0
DAFF Qld	12.9	21.6	0	6.4	10.6	28.0	56.5	9.1	14.6	3.6	0	3.9
DPI NSW	9.6	8.0	1.1	12.2	19.0	1.1	29.0	3.8	3.6	2.7	2.4	7.8
DPI Vic	11.4	38.7	0.2	0.2	0.7	4.3	42.5	2.2	0.4	0.7	0.3	2.5
ARI Vic	0.4	0.2	0	0.7	0.8	0.7	2.7	0.3	0.9	0	0	0.2
PIRSA	3.8	1.8	0	2.9	0.6	1.1	14.3	1.9	3.0	1.6	0.5	2.1
DAFWA	8.1	3.0	2.2	4.3	5.2	2.7	2.2	3.5	1.6	1.8	2.0	2.5
Fisheries WA	0.4	2.4	0	1.4	1.4	0	0.4	0	0	0.4	0	0.3
DPIPWE	2.0	1.2	0	0	4.2	0	0	0	0	0	0	0
DoR	2.7	2.4	0	0.3	0	0	2.1	0	0.1	0.1	0.1	0

[13] CSIRO data for plant health, invasive weed species and invasive animal species updated in Table 7, Figure 12 and Figure 13

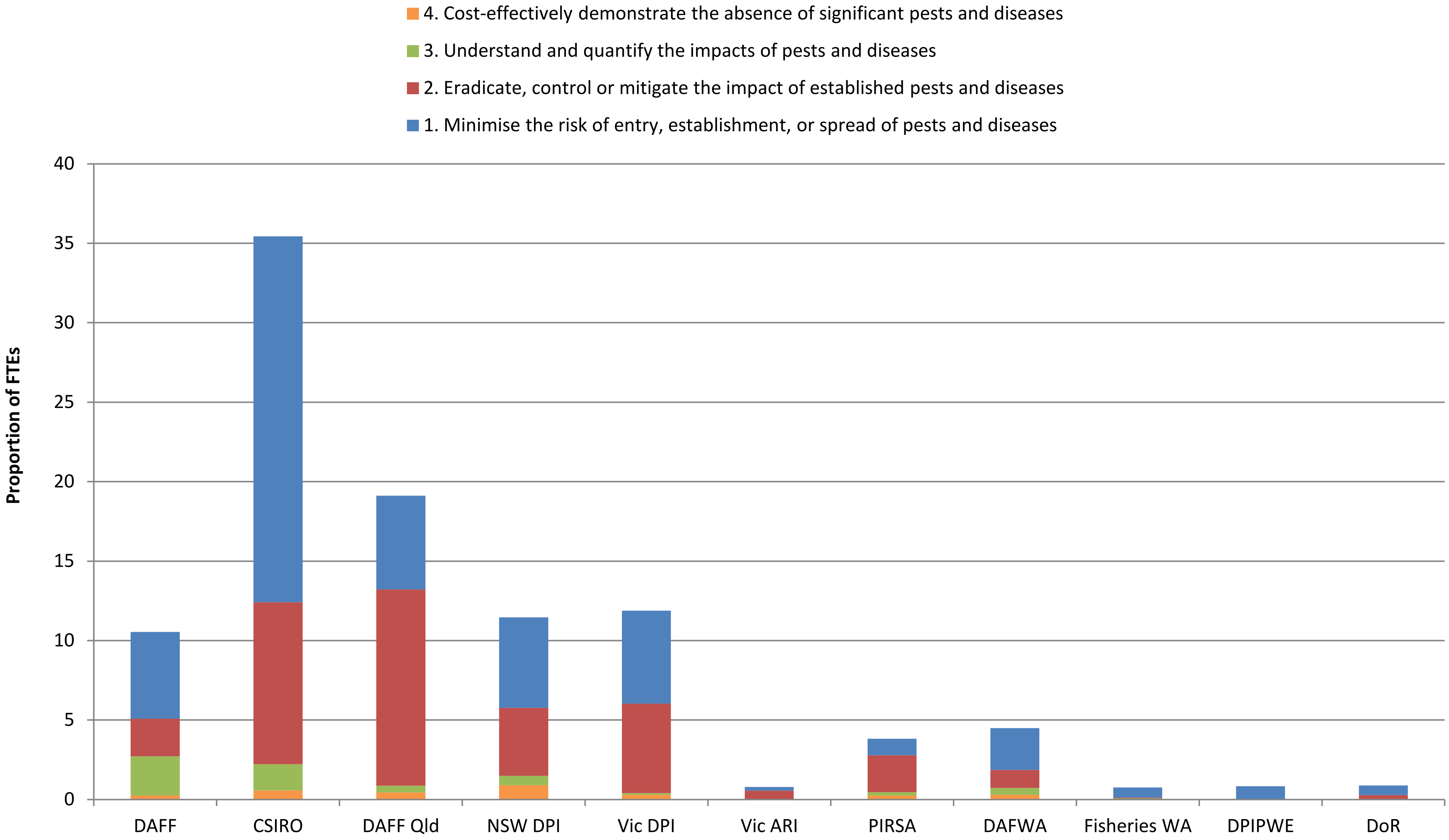

Figure 12. Proportion of full time equivalent (FTE) staff in biosecurity R&D by national R&D priority by organisation

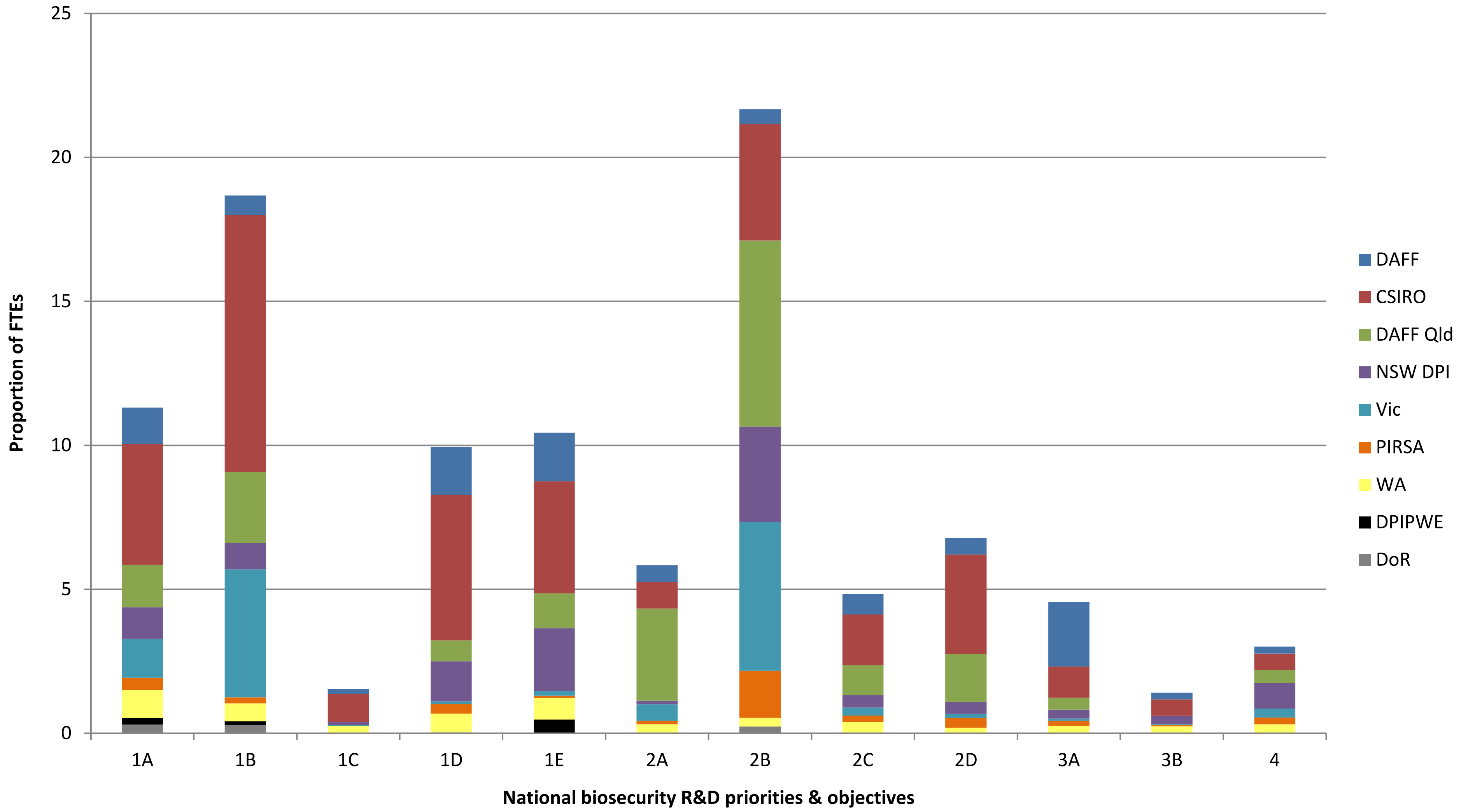

Figure 13. Proportion of full time equivalent (FTE) staff in biosecurity R&D by national R&D priority/objective by organisation[14]

[14] Data for Vic includes DPI Vic and ARI and data for WA includes DAFWA and Department of Fisheries

3.1.4. Discipline

FTEs were collected against disciplines for each sector and were listed as recorded by organisations. Capability existed in a large number of disciplines across the various sectors, demonstrating the complexity of biosecurity R&D. It should be noted that for CSIRO discipline data was incomplete for plant health, invasive weed species, invasive animal species and generic/cross-sectoral R&D, and therefore some capability in CSIRO for certain disciplines is not captured here[15]. However data for animal health disciplines is complete.

In the animal health sector, R&D capability existed in 31 disciplines across all 11 organisations surveyed (Table 8). The majority of R&D was performed by staff with expertise in molecular biology, accounting for 38.4 FTEs in animal health. Capability was also high in diagnostics (28.6 FTEs), immunology (20 FTEs) and bacteriology (17 FTEs). However approximately half the disciplines contained less than 3 FTEs. Some of these included entomology (1.8 FTEs), biochemistry (1.2 FTEs), toxicology (1.2 FTEs), ecology (0.3 FTEs), mycology (0.3 FTEs), protozoology (0.2 FTEs), information management (0.1 FTEs) and risk analysis (0.1 FTEs). These disciplines each represented less than 1% of animal health FTEs, making them particularly vulnerable. In addition, these disciplines and several others (e.g. diagnostics, ecology, histology, mycology and toxicology) had experts in only one organisation. In contrast, for some disciplines capability existed in several organisations, for example, anatomical pathology and bacteriology expertise was present in seven organisations, and epidemiology and virology experts existed in six organisations. For the remaining disciplines, expertise was present in two or three organisations.

In the plant health sector, R&D capability existed in 43 disciplines across eight organisations (Table 8). The majority of capability was in the discipline of entomology, with 86.6 FTEs accounting for 25% of the total FTEs in plant health. A large amount of capability also existed in the disciplines of pathology (50.1 FTEs) and mycology (47.9 FTEs), representing 14% of FTEs. Other disciplines with relatively high capabilities included risk analysis (39.3 FTEs)[16], disease and pest resistance (28.7 FTEs), molecular biology (19.6 FTEs), nematology (16.5 FTEs) and virology (13.3 FTEs). However 27 of the 43 disciplines had low capabilities (less than 3 FTEs each) and are therefore particularly vulnerable. Some of these disciplines were acharology (0.2 FTEs), bee pathology (0.6 FTEs), biological control (0.2 FTEs), geospatial information systems (GIS; 0.9 FTEs), stored grains engineering (0.2 FTEs), spatial ecology (0.6 FTEs), population ecology (0.4 FTEs) and taxonomy (1.3 FTEs). The lowest capabilities were in the disciplines of agronomy, biometrics, international plant protection, microscopy and systematics, each accounting for only 0.1 FTEs. Similar to the animal health sector, these disciplines and others (e.g. evolutionary biology, functional genomics and microbiology) had experts in only one organisation. In contrast entomology, nematology, pathology, disease and pest resistance and virology experts existed in at least five organisations. The majority of remaining disciplines had experts in only two or three organisations.

R&D capability in the invasive weed species sector existed in 15 disciplines across seven organisations (Table 8). The majority of R&D was performed by staff with expertise in

[15] 8.4/58.8 FTEs for plant health not recorded, 8.9/13.8 FTEs from invasive weed species not recorded, 9.7/10.3 FTEs not recorded for invasive animal species, and 3.6/7.3 FTEs not recorded for generic/cross-sectoral R&D

[16] The majority of R&D capability in risk analysis (94%) existed in DAFF

agronomy (14.6 FTEs), ecology (12.1 FTEs), biological control (9.9 FTEs) and weed science (7 FTEs). Nine of the 15 disciplines accounted for less than 2 FTEs each, making them particularly vulnerable. These included entomology (1.4 FTEs), herbicide application (1.8 FTEs), modelling (0.6 FTEs), pathology (1 FTE), spatial ecology (1 FTE) and weed control (1 FTE). Disciplines with extremely low capabilities included molecular biology (0.1 FTEs), taxonomy (0.1 FTEs) and population genetics (0.2 FTEs). These disciplines are therefore the most vulnerable. Some disciplines in invasive weed species existed in multiple organisations. For instance, ecology R&D was performed in five organisations and biological control R&D was performed in four organisations; however all remaining disciplines contained expertise in only one or two organisations.

In the invasive marine species sector, R&D capability existed in nine disciplines across five organisations (Table 8). The majority of R&D was performed by staff with expertise in surveillance (5.4 FTEs), ecology (4.4 FTEs) and molecular biology (2.3 FTEs). These disciplines represented 37%, 31% and 16% of invasive marine species capability respectively. Five of the nine disciplines accounted for less than 1 FTE each. These included GIS (0.2 FTEs), modelling (0.1 FTEs), oceanography (0.1 FTEs), risk analysis (0.7 FTEs), and taxonomy (0.1 FTEs). Therefore these disciplines are particularly vulnerable. Surveillance R&D was conducted across four organisations including DPI NSW, DPI Vic, PIRSA and Fisheries WA. Ecology R&D had capability in three organisations, modelling and molecular biology had capability in two organisations and the remaining disciplines contained capability in only one organisation.

R&D capability in the invasive animal species sector existed in 15 disciplines across six organisations (Table 8). The majority of R&D was performed by staff with expertise in population ecology (12.4 FTEs) and ecology (7.1 FTEs). These disciplines represented 33% and 19% of capability respectively. Eight of the 15 disciplines accounted for 1 or less FTEs each. These included behavioural ecology (1 FTE), communications (1 FTE), epidemiology (1 FTE), surveillance (0.9 FTEs), taxonomy (0.1 FTEs), biometrics (0.4 FTEs), ecological modelling (0.6 FTEs) and risk analysis (0.6 FTEs). These disciplines therefore represent the most vulnerable for this sector. Ecology and population ecology R&D was performed across four and five organisations respectively and toxicology R&D was conducted in three organisations. In contrast, for remaining disciplines, capability existed in only one or two organisations.

For R&D that was classified into the generic/cross-sectoral group, capability existed in 14 disciplines across five organisations (Table 8). The majority of R&D was performed by staff with expertise in economics (9.5 FTEs)[17], risk analysis (6.9 FTEs) and information technology (IT) and information management (3.6 FTEs). These disciplines accounted for 31%, 23% and 12% of FTEs respectively. Half of the disciplines accounted for less than 1 FTE each. These included biometrics (0.8 FTEs), bioinformatics (0.1 FTEs), ecological modelling (0.3 FTEs), GIS (0.8 FTEs), molecular biology (0.1 FTEs), pathology (0.1 FTEs) and proteomics (0.5 FTEs). For generic/cross-sectoral R&D, risk analysis R&D was conducted by the greatest number of organisations, including DAFF, CSIRO, DAFF Qld and DPI Vic. Economics R&D was conducted in three organisations, however all other disciplines had capabilities in no more than two organisations.

[17] The majority of capability in economics R&D (82%) existed in DAFF

For some disciplines, capability was low across multiple sectors (Table 8). Biometrics, GIS, taxonomy and modelling were particularly vulnerable. For instance, capability in biometrics was low for plant health, invasive animal species and the generic/cross-sectoral group. There was no biometrics capability for animal health, invasive weed species or invasive marine species. Capability in GIS was low for plant health, invasive marine species and the generic/cross-sectoral category. Remaining sectors had no GIS capability. There was low capability in modelling for plant health, invasive weed species, invasive marine species, invasive animal species and the generic/cross-sectoral group, with no modelling capability in the animal health sector. There was low capability in taxonomy for plant health, invasive weed species, invasive marine species and invasive animal species, with no taxonomy expertise in animal health.

Other disciplines also had low capabilities across multiple sectors (Table 8). For example, capability in toxicology was low for animal health, invasive animal species and generic/cross-sectoral R&D. Entomology capability was low for animal health and invasive weed species, however capability was high for the plant health sector. Capability in risk analysis was low for animal health, invasive weed species, invasive marine species, and invasive animal species, however it was higher for the plant health sector and generic/cross-sectoral R&D.

For information on discipline capability by organisation, refer to the organisational summaries (page 103).

Key issues

- Low capability across multiple disciplines and in many cases capability existing in only one organisation. These disciplines are particularly vulnerable.
- Discipline capability scattered across organisations highlighting the importance of collaboration and coordination of R&D activities between organisations. Scattered capability also suggests there could be difficulties with determining a cross-sectoral relationship model for R&D activities (i.e. identification of major, support, link agencies).

Table 8. Full time equivalent (FTE) staff in biosecurity R&D by discipline

Biosecurity sector	Discipline	DAFF	CSIRO	DAFF Qld	DPI NSW	DPI Vic	ARI Vic	PIRSA	DAFWA	Fisheries WA	DPIPWE	DoR	Total
Animal health	Anatomical pathology		3.0	0.8	0.1	4.0				0.3	0.6	1.5	**10.2**
	Animal science		5.8								3.3		**9.1**
	Bacteriology		1.0	3.2	7.2	4.0			0.5		0.2	1.0	**17.0**
	Biochemistry			1.2									**1.2**
	Bioinformatics		3.0										**3.0**
	Clinical pathology			4.5					2.3				**6.8**
	Diagnostics		28.6										**28.6**
	Ecology						0.3						**0.3**
	Entomology		0.5	0.3		1.0							**1.8**
	Epidemiology		3.0	8.3	0.8	1.3		0.5	2.2				**16.0**
	Field/WHS			0.5									**0.5**
	Histology			0.9									**0.9**
	Immunology		15.0		1.9						3.2		**20.1**
	Information management			0.1									**0.1**
	Laboratory support								2.9				**2.9**
	Media/Kitchen			0.1									**0.1**
	Microbiology	0.1	1.0			9.4							**10.5**
	Microscopy		5.0										**5.0**
	Molecular biology		36.6	1.3						0.5			**38.4**

Biosecurity sector	Discipline	DAFF	CSIRO	DAFF Qld	DPI NSW	DPI Vic	ARI Vic	PIRSA	DAFWA	Fisheries WA	DPIPWE	DoR	Total
	Mycology			0.3									**0.3**
	Parasitology			3.9	0.8				1.1				**5.8**
	Pathobiology					2.0							**2.0**
	Protein Chemistry		9.4										**9.4**
	Protozoology			0.2									**0.2**
	Risk analysis	0.01								0.1			**0.1**
	Science	1.5											**1.5**
	Serology		10.7	2.9									**13.6**
	Tissue culture		2.0										**2.0**
	Toxicology								1.2				**1.2**
	Veterinarian	12.6	1.0	0.1	0.8								**14.5**
	Virology		34.1	3.9	19.8	4.4			0.3			1.6	**64.1**
Total		**14.2**	**159.7**	**32.2**	**31.4**	**26.1**	**0.3**	**0.5**	**10.5**	**0.8**	**7.3**	**4.0**	**287.0**
Plant health	Acharology				0.2								**0.2**
	Advisory								0.2				**0.2**
	Agronomy		0.1										**0.1**
	Auditing in biosecurity				0.5								**0.5**
	Bacteriology			1.3	1.5	2.0							**4.8**
	Bee pathology		0.6										**0.6**
	Bioinformatics		0.7									0.1	**0.8**
	Biological control								0.2				**0.2**

Biosecurity sector	Discipline	DAFF	CSIRO	DAFF Qld	DPI NSW	DPI Vic	ARI Vic	PIRSA	DAFWA	Fisheries WA	DPIPWE	DoR	Total
	Biometrics				0.1								**0.1**
	Breeding		0.4										**0.4**
	Capacity building	1.1											**1.1**
	Diagnostics	0.8				3.0			2.2				**6.0**
	Disease & pest resistance		14.8	6.0	5.4			2.3	0.2				**28.7**
	Ecology	1.0	1.1										**2.1**
	Emergency response	0.7											**0.7**
	Entomology	3.6		46.7	14.4	13.1		5.2	1.3			2.2	**86.6**
	Eradication								1.0				**1.0**
	Evolutionary biology		2.1										**2.1**
	Functional genomics		0.7										**0.7**
	Geospatial Information Systems	0.8			0.1								**0.9**
	Horticulture					0.2			1.1				**1.3**
	IT and information management	1.4		1.0									**2.4**
	International plant protection	0.1											**0.1**
	Microbiology					3.0							**3.0**
	Microscopy				0.1								**0.1**
	Modelling		1.9	1.0	0.2								**3.1**

Biosecurity sector	Discipline	DAFF	CSIRO	DAFF Qld	DPI NSW	DPI Vic	ARI Vic	PIRSA	DAFWA	Fisheries WA	DPIPWE	DoR	Total
	Molecular biology		16.9	1.0		1.6						0.1	**19.6**
	Mycology			8.5	6.2	27.4		5.8					**47.9**
	Nematology		0.8	9.0	0.4	2.3		2.6	1.4				**16.5**
	Pathology	4.0	7.0	23.0	9.3				5.7			1.1	**50.1**
	Pest control technology	1.0											**1.0**
	Pest management								3.7				**3.7**
	Policy	1.7							1.8				**3.5**
	Population ecology		0.4										**0.4**
	Quarantine	0.1						1.4	0.2				**1.7**
	Risk analysis	37.0	1.9		0.4								**39.3**
	Soil microbial ecology		0.3	2.7	0.2			1.2					**4.4**
	Spatial ecology	0.2	0.4										**0.6**
	Stored grains engineering		0.2										**0.2**
	Surveillance	0.9			0.3				1.4				**2.6**
	Systematics		0.1										**0.1**
	Taxonomy					1.3							**1.3**
	Virology			4.2	0.8	7.2		0.3	0.8				**13.3**
Total		**54.4**	**50.4**	**104.3**	**40.0**	**61.2**	**0**	**18.8**	**21.4**	**0**	**0**	**3.5**	**353.8**

Biosecurity sector	Discipline	DAFF	CSIRO	DAFF Qld	DPI NSW	DPI Vic	ARI Vic	PIRSA	DAFWA	Fisheries WA	DPIPWE	DoR	Total
Invasive weed species	Agronomy			6.0	8.6								**14.6**
	Biological control			0.5	4.6	4.0		0.8					**9.9**
	Weed control							1.0					**1.0**
	Ecology	1.0	3.4			6.4	0.3	1.0					**12.1**
	Entomology			0.5	0.9								**1.4**
	Herbicide application				1.8								**1.8**
	Molecular biology		0.1										**0.1**
	Modelling		0.6										**0.6**
	Pathology					1.0							**1.0**
	Population ecology		0.6	5.8									**6.4**
	Population genetics		0.2										**0.2**
	Risk analysis				1.9	2.5							**4.4**
	Spatial ecology							1.0					**1.0**
	Taxonomy						0.1						**0.1**
	Weed science			7.0									**7.0**
Total		**1.0**	**4.9**	**19.7**	**17.8**	**13.9**	**0.4**	**3.8**	**0**	**0**	**0**	**0**	**61.5**

Biosecurity sector	Discipline	DAFF	CSIRO	DAFF Qld	DPI NSW	DPI Vic	ARI Vic	PIRSA	DAFWA	Fisheries WA	DPIPWE	DoR	Total
Invasive marine species	Ecology				1.2		0.1	3.2					**4.4**
	Geospatial Information Systems					0.2							**0.2**
	Management							1.2					**1.2**
	Modelling				0.1			0.1					**0.1**
	Molecular biology							0.5		1.8			**2.3**
	Oceanography							0.1					**0.1**
	Risk Analysis							0.7					**0.7**
	Surveillance				0.4	0.5		0.5		4.0			**5.4**
	Taxonomy						0.1						**0.1**
Total		**0**	**0**	**0**	**1.7**	**0.7**	**0.1**	**6.1**	**0**	**5.8**	**0**	**0**	**14.4**
Invasive animal species	Behavioural ecology				0.9		0.1						**1.0**
	Biological control				1.8								**1.8**
	Biometrics						0.4						**0.4**
	Communications								1.0				**1.0**
	Ecology		0.02	5.2			0.9	1.0					**7.1**
	Ecological modelling		0.6										**0.6**
	Epidemiology							1.0					**1.0**
	Modelling				0.9		0.4						**1.3**
	Pest control			1.0	1.8								**2.8**

Biosecurity sector	Discipline	DAFF	CSIRO	DAFF Qld	DPI NSW	DPI Vic	ARI Vic	PIRSA	DAFWA	Fisheries WA	DPIPWE	DoR	Total
	Population ecology			1.0	1.8		2.7	2.3	4.6				**12.4**
	Risk analysis						0.6						**0.6**
	Spatial ecology						0.1		1.8				**1.9**
	Surveillance				0.9								**0.9**
	Taxonomy						0.1						**0.1**
	Toxicology			2.0	1.4		0.8						**4.2**
Total		**0**	**0.6**	**9.2**	**9.5**	**0**	**6.1**	**4.3**	**7.4**	**0**	**0**	**0**	**37.1**
Generic/Cross-sectoral	Bioinformatics											0.1	**0.1**
	Biometrics	0.8											**0.8**
	Ecology	3.3											**3.3**
	Ecological modelling		0.3										**0.3**
	Economics	7.8	0.9			0.8							**9.5**
	Geospatial Information Systems	0.3	0.5										**0.8**
	IT and information management	2.8				0.8							**3.6**
	Modelling	1.9											**1.9**
	Molecular biology											0.1	**0.1**
	Pathology	0.1											**0.1**
	Proteomics		0.5										**0.5**

Biosecurity sector	Discipline	DAFF	CSIRO	DAFF Qld	DPI NSW	DPI Vic	ARI Vic	PIRSA	DAFWA	Fisheries WA	DPIPWE	DoR	Total
	Risk analysis	5.4	0.5	0.5		0.5							**6.9**
	Social sciences	2.0	0.9										**2.9**
	Toxicology			1.4									**1.4**
Total		**24.1**	**3.7**	**1.9**	**0**	**2.1**	**0**	**0**	**0**	**0**	**0**	**0.3**	**32.0**

3.2. Investment

3.2.1. Capability investment through staff wages

Comparison between sectors

Based on the data provided during the period January 2012 - June 2012, approximately $66,411,070 is spent per annum on wages (base wage, not including on-costs) for biosecurity R&D capability across the various sectors (see Table 9 and Figure 14). Approximately 45% of this amount ($29.6 million) was invested in wages for the plant health sector, 36% ($23.8 million) in wages for the animal health sector, 8% ($5.5 million) in wages for invasive weed species, 5% ($3.3 million) in wages for invasive animal species, 5% ($3.2 million) in wages for the generic/cross sectoral group and 1% ($0.9 million) in wages for invasive marine species. As expected, these values approximately reflect the percentage of FTEs for biosecurity R&D capability across the sectors (see human capability section, page 18).

Comparison between organisations (cross-sectoral)

Assessing the cross-sectoral investment in capability by organisation, CSIRO spent the greatest proportion of funds on wages for biosecurity R&D. In total $22,100,352 was spent, accounting for 33% of the total amount spent nationally (see Table 9 and Figure 14). DAFF Qld spent $12,924,866, representing 19% of funds nationally, DPI NSW spent $8,468,762 and DAFF spent $8,520,720, representing approximately 13% for both organisations, and DPI Vic spent $7,277,796, representing 11% of the total funds spent on biosecurity R&D capability. DAFWA and PIRSA spent only 4% and 3% of the total funds respectively, while DPIPWE, DoR, ARI Vic and Fisheries WA each spent only 1% of the total national funding for biosecurity R&D capability. These values approximately reflect the percentage of FTEs for biosecurity R&D capability across the sectors (see human capability section, page 18 and compare Figure 2 with Figure 14).

Comparison between organisations (by sector)

Assessing the sectors individually, CSIRO ($13.6 million), DPI NSW ($2.6 million) and DAFF Qld ($2.4 million) spent the greatest amount of staff wages for the animal health sector (Table 9 and Figure 14). This was expected since these organisations contained the highest capabilities in the animal health sector (see Figure 1).

For the plant health sector, DAFF Qld ($8.2 million), CSIRO ($5.6 million), DAFF ($4.6 million) and DPI Vic ($4.4 million) spent the greatest amount on staff wages (Table 9 and Figure 14). As expected these organisations also contained the highest capabilities in the plant health sector (see Figure 1). However although DPI Vic (61.2 FTEs) had higher capability than CSIRO (58.8 FTEs) and DAFF (54.4 FTEs), they spent less money than these organisations on staff wages.

For invasive weed species, DPI NSW ($1.5 million), DAFF Qld ($1.4 million) and CSIRO ($1.3 million) spent the largest amount of funds on staff wages (Table 9 and Figure 14). This was expected since they contained the highest capabilities in the invasive weed species sector (see Figure 1). Although DAFF Qld (19.7 FTEs) had higher capability than DPI NSW (17.8 FTEs), they spent less money on staff wages.

For the invasive marine species sector, Fisheries WA ($0.5 million) and PIRSA ($0.4 million) spent the greatest amount on staff wages (Table 9 and Figure 14). These organisations also contained the highest capabilities in the invasive marine species sector (see Figure 1). However although PIRSA (6.1 FTEs) had higher capability than Fisheries WA (5.8 FTEs), they spent less money on staff wages.

For the invasive animal species sector, CSIRO ($0.91 million) and DPI NSW ($0.86 million) spent the greatest amount on staff wages (Table 9 and Figure 14). This was expected since these organisations also had the highest capabilities in this sector (see Figure 1).

For generic/cross-sectoral R&D, DAFF ($2.2 million) and CSIRO ($0.8 million) spent the greatest amount on staff wages (Table 9 and Figure 14), which was expected since these organisations had the highest capabilities (see Figure 1).

For further information on amounts spent on staff wages for each organisation, refer to the organisational summaries (page 103).

Table 9. Investment in biosecurity R&D through staff wages ($)

	DAFF	CSIRO	DAFF Qld	DPI NSW	DPI Vic	ARI Vic	PIRSA	DAFWA	Fisheries WA	DPIPWE	DoR	Total
Animal health	1,664,406	13,595,257	2,416,688	2,604,494	1,715,685	21,437	44,057	773,000	84,800	543,326	337,373	**23,800,523**
Plant health	4,588,441	5,587,367	8,229,771	3,484,625	4,369,890	0	1,365,750	1,716,000	0	0	269,046	**29,610,890**
Invasive weed species	89,671	1,249,947	1,391,465	1,493,988	994,449	36,293	253,131	0	0	0	0	**5,508,944**
Invasive marine species	0	0	0	28,501	50,475	7,069	352,692	0	497,000	0	0	**935,738**
Invasive animal species	0	911,562	735,442	857,153	0	494,656	301,353	0	0	0	0	**3,300,166**
Generic/Cross-sectoral	2,178,203	756,218	151,500	0	147,297	0	0	0	0	0	21,591	**3,254,809**
Total	**8,520,720**	**22,100,352**	**12,924,866**	**8,468,762**	**7,277,796**	**559,455**	**2,316,983**	**2,489,000**	**581,800**	**543,326**	**628,010**	**66,411,070**

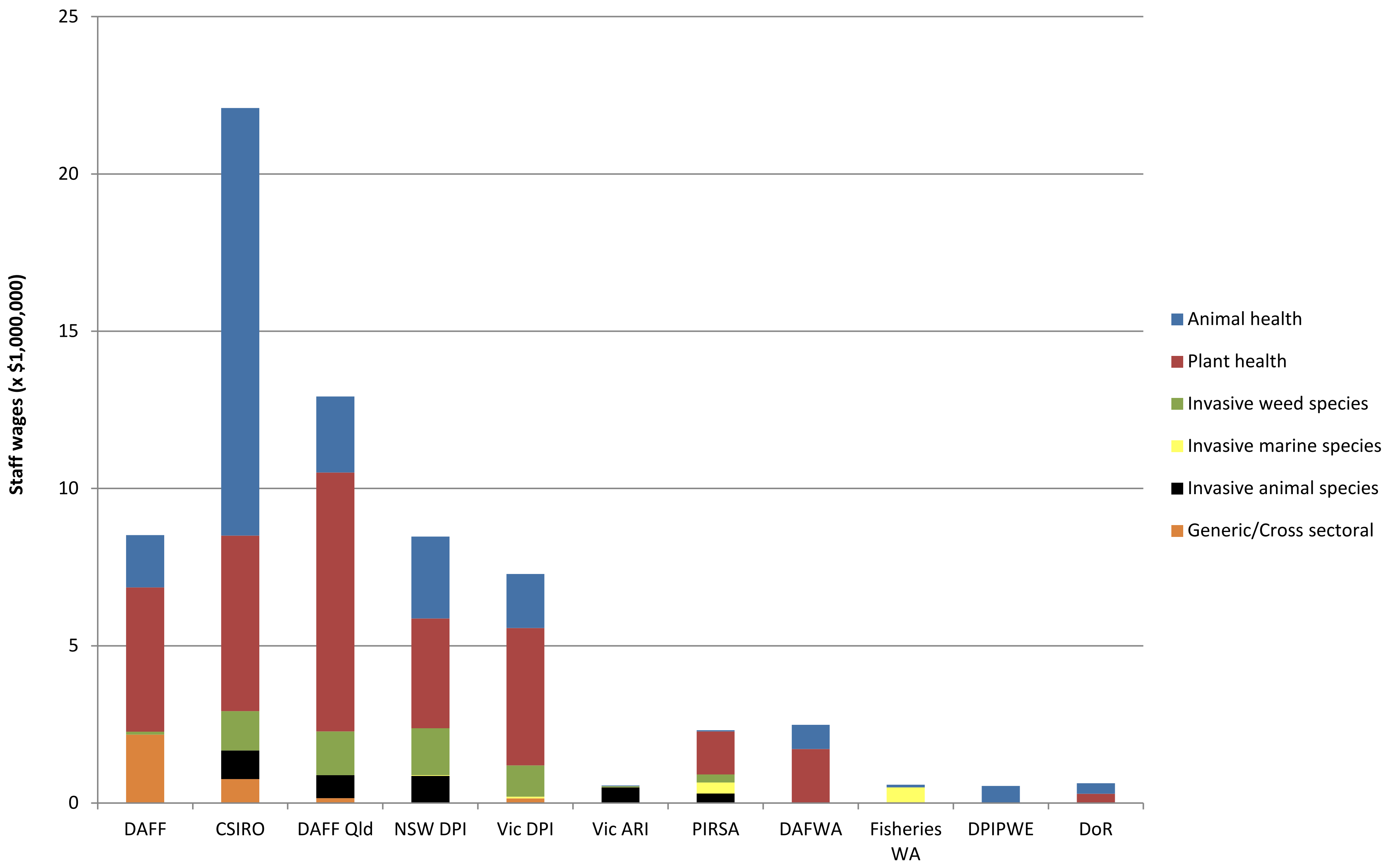

Figure 14. Investment in biosecurity R&D capability through staff wages (x $1,000,000)

3.2.2. External funding – amounts

Comparison between sectors

External funding received by organisations to support biosecurity R&D in the year 2011 amounted to $72,365,480 nationally (Table 10). This represented over $6 million more than the total investment in wages for capability. It is expected that these funds were utilised to support staff wages and provide other resources (e.g. equipment) required to conduct the R&D. The large majority of external funding was spent on R&D that is generic/cross sectoral (Table 10). In total $28,666,277 was received, representing 40% of the external funds across the sectors. However it should be noted that 98% of this amount went to DAFF Qld, for which external investment was not allocated to each sector, but was all provided as generic/cross sectoral (see Table 10 and Figure 15). Therefore most of this generic/cross-sectoral funding would actually be directed to R&D for the animal health, plant health, invasive weed species or invasive animal species sectors.

A large proportion of external funding was directed to the plant health sector (Table 10). In total, $28,185,708 was received, representing 39% of the external funds across the sectors. This was expected given that the plant health sector had the greatest capability of the sectors (45% of FTEs; Table 1). In comparison animal health received $8,939,207, representing only 12% of external funding. This was despite the relatively large percentage of FTEs (35%) allocated to this sector (Table 1). For the remaining sectors, invasive animal species received $3,679,100, representing 5% of external funding, invasive weed species received $2,325,188, representing 3% and invasive marine species received $570,000, representing only 1% of total external funds (Table 10). Of interest was the observation that although the invasive weed species sector conducted a greater proportion of R&D than invasive animal species (9% compared to 6% respectively), they received a lower percentage of external funding (3% for weeds compared to 5% for invasive animals).

Comparison between organisations (cross-sectoral)

Assessing the total (cross-sectoral) external investment by organisation, DAFF Qld received the greatest amount of external funds (see Table 10 and Figure 15). Approximately $28 million was received, accounting for 39% of the total national external investment. This represented approximately double the external funding received by CSIRO which amounted to approximately $14 million and represented 20% of the total amount nationally. This was interesting considering that CSIRO had 10% more R&D capability than DAFF Qld (compare Figure 15 with Figure 2). DPI NSW received approximately $12.6 million, representing 17% of the total national external investment. In contrast, DPI Vic received approximately $5.6 million, representing only 8% of external funds. This was despite having greater capability than DPI NSW (13% of FTEs for Vic compared to 12% for NSW). Despite capability accounting for 4% of FTEs nationally, PIRSA received 11% of external funds. This amounted to approximately $7.8 million. Although DAFWA conducted a greater proportion of R&D than PIRSA (5% compared to 4% respectively), external funding for DAFWA ($0.56 million) amounted to only 1% of the total invested nationally. DPIPWE ($1.15 million) and ARI Vic ($1.5 million) both received 2% of external funding (Table 10), despite each organisation containing only 1% of the capability nationally (see Figure 2). Fisheries WA received only $150,000, accounting for 0.2% of external funds (Table 10). Similarly, DoR received a small proportion of external funding, receiving $45,000, representing only 0.1% of external funds.

Comparison between organisations (by sector)

Assessing the sectors individually, CSIRO received the greatest amount of external funding for the animal health sector (see Table 10 and Figure 15). This was not surprising considering they had the greatest capability in this sector (56% of FTEs; see Figure 1). External funding for CSIRO amounted to approximately $5.4 million, representing 61% of total external funding for animal health. DPI NSW received approximately $1.4 million, representing 16% of the external funding and DPIPWE received $1.15 million, representing 13% of external funding for animal health. Other organisations that obtained external funding towards animal health R&D included DPI Vic, PIRSA and Fisheries WA. It is likely some of the cross-sectoral DAFF Qld funding was directed towards animal health, especially given they had the second largest capability in this sector (Figure 1).

For the plant health sector, CSIRO received approximately $8.7 million in external funding, representing 31% of the total external funding for the plant health sector (Table 10 & Figure 15). This was despite CSIRO containing only the third highest capability in plant health (see Figure 1). However it is certain that some of the cross-sectoral DAFF Qld funding was directed towards plant health, especially given they had the greatest capability in this sector (Figure 1). DPI Vic, despite having the second highest capability, received only 14% of external funding for plant health (approximately $3.9 million; Table 10). In contrast DPI NSW and PIRSA received high amounts of external funding, despite lower capabilities than DPI Vic. DPI NSW received approximately $8.6 million and PIRSA received approximately $6.4 million, representing 30% and 23% of external funds respectively. DAFWA and DoR also received external funding towards plant health R&D, although the amounts received represented less than 2% of the total external funds for plant health. In contrast, DAFF did not receive any external funding for plant health R&D, despite having the fourth highest capability (compare Table 10 with Figure 1). This reflects the type of R&D conducted by DAFF, the majority of which was desk-based R&D in the disciplines of risk analysis, pathology and entomology (see Table 8).

Only three organisations received external funding for the invasive weed species sector (Table 10 & Figure 15). This was despite seven organisations conducting R&D in this sector (Figure 1). DPI Vic received approximately $1.2 million, representing 51% of external funds for this sector. DPI NSW received approximately $0.9 million, accounting for 38% of invasive weed species funding. The remaining 11% (approximately $0.3 million) of external funding was received by PIRSA. It is likely some of the cross-sectoral DAFF Qld funding was directed towards invasive weed species, especially given they conduct the greatest proportion of R&D (Figure 1). Although DAFF, CSIRO and ARI Vic conducted invasive weed species R&D, they do not receive external funding towards it.

External funding for invasive marine species was received by the same three organisations as invasive weed species (Table 10 & Figure 15). PIRSA received 76% ($435,000) of the external funds for invasive marine species. This was not surprising given they had the greatest capability (Figure 1). DPI Vic received 15% ($85,000) and DPI NSW received 9% ($50,000). Although Fisheries WA conducted the second greatest proportion of R&D for invasive marine species (Figure 1), they did not report any external funding towards this sector. Instead, all their external funding was reported to be allocated to animal health.

For the invasive animal species sector, DPI NSW and ARI Vic received the majority of external funding (Table 10 & Figure 15). DPI NSW received approximately $1.7 million (46%)

and ARI Vic received approximately $1.5 million (42%). The remaining 13% of external funds (approximately $0.5 million) were received by PIRSA. Although CSIRO and DAFWA conducted R&D for invasive animal species (Figure 1), they did not report any external funding towards this sector (Table 10). This is interesting given CSIRO had the greatest capability for this sector (Figure 1). It is possible some of the cross-sectoral DAFF Qld funding was directed towards invasive animal species, especially given they had the third largest capability in this sector (Figure 1).

For generic/cross-sectoral R&D, external funding was received by DAFF and DAFF Qld (Table 10 & Figure 15). All the funding received by DAFF went towards the Biosecurity Information Network (BIN). As mentioned previously, 98% of external funding for generic/cross-sectoral R&D went to DAFF Qld, although it is certain this funding would actually be spread between the animal health, plant health, invasive weed species and invasive animal species sectors in which DAFF Qld conduct R&D (see Figure 1). CSIRO, DPI Vic and DoR all conducted generic/cross-sectoral R&D (Figure 1), however they did not receive external funding towards it (Table 10).

For further information on external funding received by each organisation, refer to the organisational summaries (page 103).

Key issues

- External funding represents a large amount of 'soft money' that is unstable funding. Reduction or loss of external funding would lead to loss of capability and loss of R&D outputs.
- Some sectors are particularly vulnerable as they receive a relatively small amount of external funding. Invasive weed species and invasive marine species appear particularly vulnerable.

Table 10. External investment in biosecurity R&D by sector ($)[18]

	DAFF	CSIRO	DAFF Qld	DPI NSW	DPI Vic	ARI Vic	PIRSA	DAFWA	Fisheries WA	DPIPWE	DoR	Total
Animal health	0	5,439,000	0	1,440,000	467,207	0	293,000	0	150,000	1,150,000	0	**8,939,207**
Plant health	0	8,731,000	0	8,589,000	3,890,708	0	6,370,000	560,000	0	0	45,000	**28,185,708**
Invasive weed species	0	0	0	886,500	1,174,688	0	264,000	0	0	0	0	**2,325,188**
Invasive marine species	0	0	0	50,000	85,000	0	435,000	0	0	0	0	**570,000**
Invasive animal species	0	0	0	1,674,100	0	1,541,000	464,000	0	0	0	0	**3,679,100**
Generic/Cross-sectoral	430,000	0	28,236,277	0	0	0	0	0	0	0	0	**28,666,277**
Total	**430,000**	**14,170,000**	**28,236,277**	**12,639,600**	**5,617,603**	**1,541,000**	**7,826,000**	**560,000**	**150,000**	**1,150,000**	**45,000**	**72,365,480**

[18] Figures represent external funds received by each organisation for biosecurity R&D

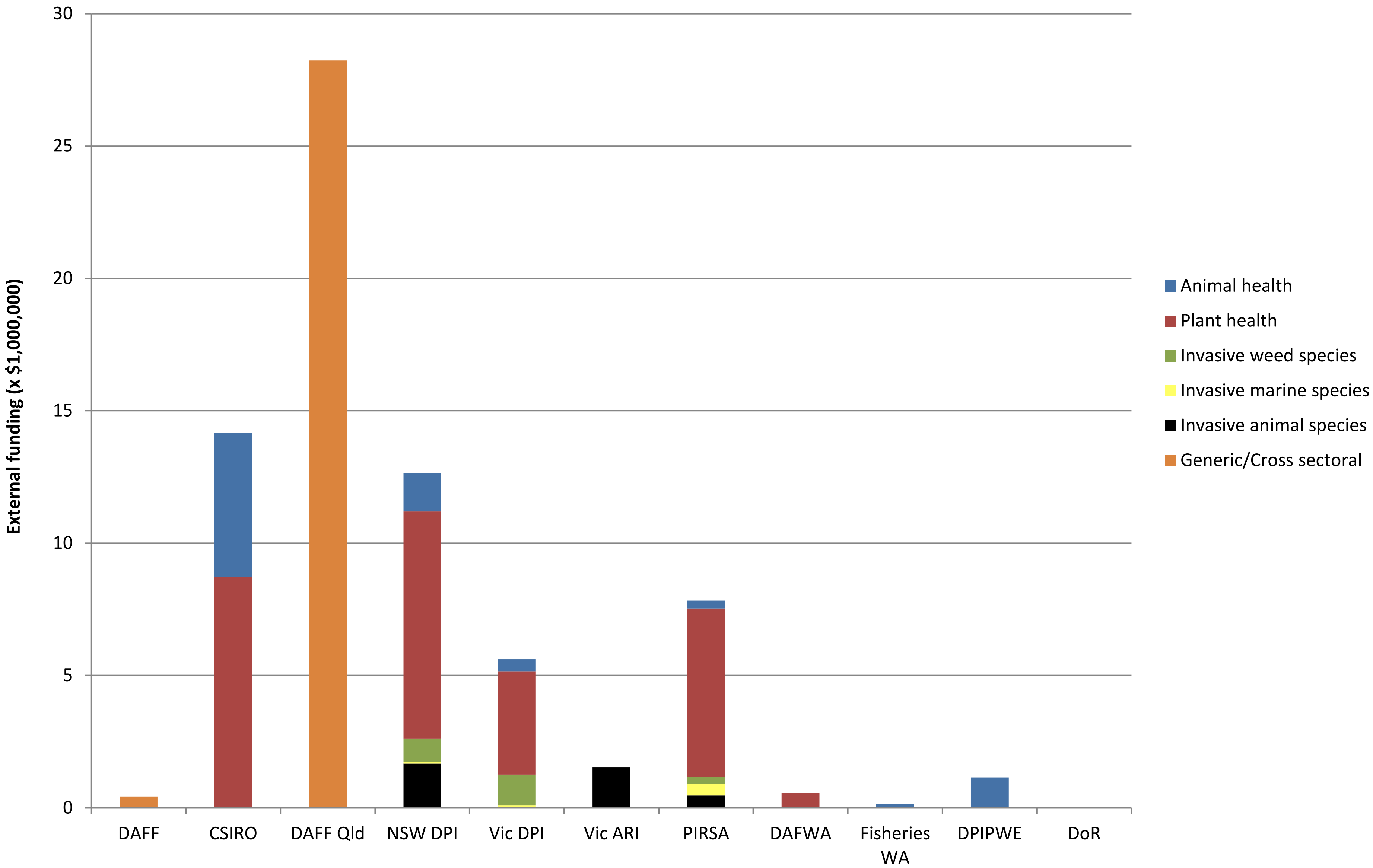

Figure 15. External investment in biosecurity R&D by sector (x $1,000,000)

3.2.3. External funding – against priority areas

External funding was allocated to the national biosecurity R&D priorities (see Appendix C). The majority of external investment was against priorities 1 and 2 (Figure 16). Priority area 1 received approximately $35.8 million, accounting for 49.5% of the total external investment and priority area 2received approximately $34.8 million, accounting for 48% of external investment. In contrast, priority 3 received approximately $1.1 million and priority 4 received approximately $0.6 million, accounting for only 1.5% and 1% the total external investment respectively (Figure 16). These figures approximately match the research effort (FTEs) against the four priorities (see Figure 10).

Comparing external investment between objectives, all objectives were externally funded except objective 1C (Table 11). Therefore objective 1C represents a funding gap for biosecurity R&D. The majority of external investment was against objectives 2B (approximately $22.3 million) and 1D (approximately $18.3 million), accounting for 31% and 25% of external funding respectively. It was not surprising that objective 2B received the greatest proportion of external funding given that the greatest amount of R&D was conducted against this objective (see Figure 11). Objective 2D also received a large amount of external funding (Table 11). Approximately $9.7 million went towards this objective, representing 13% of external funding; which again was anticipated since 12% of research effort was against this objective (Figure 11). Objective 1E received approximately $7.6 million, accounting for 10% of external funds (Table 11). This fits with the finding that 9% of R&D was conducted against this objective (Figure 11). In contrast, although a large proportion of R&D was conducted against objective 1A (13%; Figure 11), this objective only accounted for 8% ($5.6 million) of external funding (Figure 11). Objective 1B was similar, accounting for 19% of research effort (Figure 11), however receiving only 6% ($4.3 million) of external funding (Table 11). Remaining objectives received small proportions of external funding, with objective 2A receiving only 3%, and objectives 2C, 3A, 3B and priority 4 receiving only 1% each of the total external investment (Table 11). This was not surprising given that the least amount of research effort was against these objectives (Figure 11).

Comparison by sector

The animal health sector received external funding for all priority areas, with the majority of funding (67%) against priority 1 (Figure 16). This finding was not surprising given that the majority of R&D was against priority 1 (see Figure 10). Considering the objectives, external funding was received for all objectives except 1C, with the greatest proportion of investment (31%) towards objective 1E (Table 11). In contrast objectives 3A and 3B each received only 0.1% of external funds (Table 11).

For the plant health sector, all priority areas were externally funded, with priority 2 receiving the majority of external investment (67%; Figure 16). This finding was not surprising given that the majority of R&D was against priority 2 (see Figure 10). External funding was received for all objectives except 1C (Table 11). Objectives 2B and 2D received the greatest proportions of external funding for this sector, accounting for 31% and 32% of external funding respectively (Table 11). In contrast priority 4 received only 1% of the external funds.

The invasive weed species sector only received external funding against priority 2 (Figure 16). They also conducted R&D against priorities 1 and 3 (see Figure 10), however no external funding was received for this R&D (Figure 16). External funding was only received for objectives 2B and 2D, with 97% of this investment directed towards objective 2B (Table 11).

The invasive marine species sector received external funding for all four priority areas, with the majority of this against priorities 1 (50%) and 2 (34%; Figure 16). This approximately matched the research effort against the priorities (see Figure 10). All objectives were externally funded except 1C and 3B (Table 11). The greatest proportion of external funding (24%) went towards objective 1B. In contrast only 4% of external funds were against objective 1D.

The invasive animal species sector received external funding against all priority areas and objectives except objective 1C and priority area 4 (Figure 16), although they do conduct some R&D against objective 1C and priority 4 (see Figure 10). The majority of external investment was spread between priorities 1 (49%) and 2 (46%; Table 11). For the objectives, the majority of external investment was against objectives 2B (40%) and 1D (37%). In contrast, objective 1A received only 0.1% of the external funding for the invasive animal species sector.

R&D that is generic/cross-sectoral was externally funded for all priority areas (Figure 16). The majority of external funding (67%) was against priority area 1 (Figure 16) which was not surprising since the majority of R&D for this sector was also against priority area 1 (see Figure 10). External funding was received for all objectives except 1C, with the majority of funding (50%) against objective 1D (Table 11). It was interesting that objective 1D received 50% of the external funds, despite accounting for only 5% of total research effort (see Figure 10). In contrast the greatest amount of research effort for this sector (33%) was against objective 3A (see Figure 10), however this objective only received 0.4% of the external funds (Table 11). The objective which received the smallest proportion of external funding was 3B (0.3%).

Key issues

- Relatively low amounts of external funding against priority 3 (including both objectives 3A and 3B), priority 4 and objectives 1C (not externally funded at all) and 2C.

Table 11. External investment in biosecurity R&D by national priorities and objectives ($)

	National biosecurity R&D priorities and objectives												
	1A	1B	1C	1D	1E	2A	2B	2C	2D	3A	3B	4	Total
Animal health	1,043,000	1,377,207	0	800,000	2,747,000	325,000	2,285,000	60,000	69,000	10,000	10,000	213,000	**8,939,207**
Plant health	2,090,250	2,361,914	0	1,761,000	2,334,017	900,000	8,670,756	316,771	8,891,000	320,000	320,000	220,000	**28,185,708**
Invasive weed species	0	0	0	0	0	0	2,245,188	0	80,000	0	0	0	**2,325,188**
Invasive marine species	50,000	135,000	0	25,000	75,000	50,000	75,000	30,000	40,000	40,000	0	50,000	**570,000**
Invasive animal species	5,000	104,500	0	1,344,000	353,000	113,500	1,471,100	45,000	50,000	103,000	90,000	0	**3,679,100**
Generic/ Cross-sectoral	2,412,431	318,237	0	14,416,931	2,073,288	746,271	7,522,957	288,844	552,663	120,280	82,605	131,770	**28,666,277**
Total	**5,600,681**	**4,296,858**	**0**	**18,346,931**	**7,582,305**	**2,134,771**	**22,270,001**	**740,615**	**9,682,663**	**593,280**	**502,605**	**614,770**	**72,365,480**

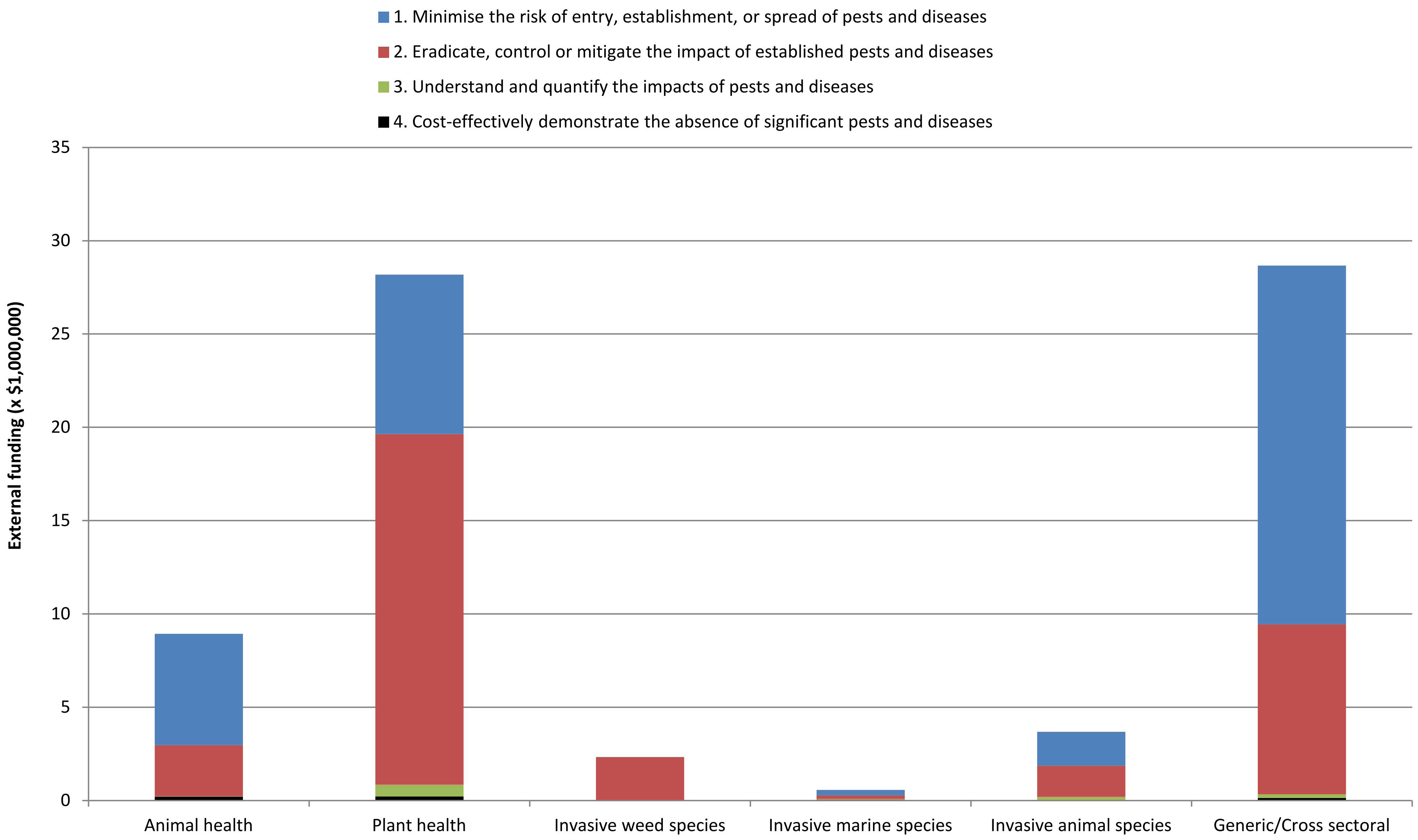

Figure 16. External investment in biosecurity R&D by national biosecurity R&D priorities (x $1,000,000)

Comparison by organisation

Comparing priority area funding by organisation, all organisations surveyed received external funding for priority area 1 (see Table 12 & Figure 17). DAFF Qld received the greatest amount of external funds against priority 1, amounting to approximately $18.8 million. This represented 52% of external funds against this priority. In contrast DoR received only 0.1% ($45,000) of the total external funds against priority 1. All organisations received external funding against priority 2 except DAFF, ARI Vic, DAFWA, Fisheries WA and DoR. CSIRO received the majority of funding against this priority area. Approximately $10.1 million was received by CSIRO, which represented 29% of the total external funding against priority area 2. In contrast, DPIPWE received $285,000, representing only 0.8% of the total external funding towards priority area 2. Only DAFF Qld, DPI NSW, PIRSA and DAFWA received external funding against priority area 3, with DPI NSW receiving the greatest amount. DPI NSW received $460,000, which represented 42% of the total external funds against priority area 3. CSIRO, DAFF Qld, DPI NSW and PIRSA were the only organisations to receive external funding against priority 4. PIRSA obtained the majority of funds. This amounted to $270,000, representing 44% of the total external funding against priority area 4.

Assessing the objectives individually, all organisations received funding for objective 1A except ARI Vic and DoR (Table 12). For this objective, DAFF Qld received the greatest amount of external funding (Table 12 & Figure 18). This amounted to approximately $2 million, representing 35% of external investment against objective 1A. In contrast DPI Vic received the least amount of external funding, accounting for only 0.4% of funds.

Objective 1B was externally funded for all organisations except ARI Vic and DAFWA (Table 12). PIRSA received the greatest amount of external funding for this objective, receiving $1.3 million, representing 30% of external funds for objective 1B (Figure 18).

Objective 1C was the only objective not externally funded for any organisations surveyed (Table 12 & Figure 18). This was despite five organisations conducting R&D against this objective (see Figure 13).

Five organisations received external funding against objective 1D (Table 12). Of these, DAFF Qld received the greatest amount of funding (Figure 18), totalling approximately $14 million, which represented 79% of external funds against objective 1D (Table 12).

Only four organisations did not receive external funding for objective 1E. These included DAFF, DAFWA, DoR and Fisheries WA (Table 12). DPI NSW, DAFF Qld and CSIRO all received large amounts of external funding against this objective (Figure 18). DPI NSW received approximately $2.8 million (36% of the funds for 1E), DAFF Qld received approximately $2 million (27%) and CSIRO received approximately $1.8 million (24%).

Objective 2A was externally funded for DAFF Qld, DPI NSW, DPI Vic, PIRSA and DPIPWE, with the majority of funds received by DAFF Qld and DPI NSW (Table 12 & Figure 18). DAFF Qld received approximately $0.75 million, representing 35% of external funds and DPI NSW received approximately $0.64 million, representing 30% of external funds for objective 2A.

External funding for objective 2B was received by CSIRO, DAFF Qld, DPI NSW, DPI Vic and PIRSA, with the majority of funds received by DAFF Qld, DPI NSW and DPI Vic (Table 12). DAFF Qld received approximately $7.5 million (34%), DPI NSW received approximately $5 (22%) and DPI Vic received approximately $4.7 million (21%) towards R&D relating to objective 2B.

Only four organisations received external funding towards objective 2C, including DAFF Qld, NSW DPI, Vic DPI and PIRSA (Table 12 & Figure 18). For this objective, PIRSA received the highest proportion (50%) of external funds.

Four organisations received funding against objective 2D, including CSIRO, DAFF Qld, NSW DPI and PIRSA (Table 12 & Figure 18). CSIRO received approximately $8.8 million, representing 91% of external funding against this objective. In contrast, PIRSA received only $129,000, representing 1% of external funds.

DAFF Qld, DPI NSW, PIRSA and DAFWA were externally funded for objective 3A (Table 12 & Figure 18). DAFWA received $320,000, representing the majority (54%) of funds. DPI NSW received $50,000, representing the lowest proportion of funds (8%).

Only three organisations received funding against objective 3B, including DAFF Qld, DPI NSW and PIRSA (Table 12 & Figure 18). DPI NSW received $410,000, representing 82% of the funding against this objective. In contrast PIRSA received $10,000, representing only 2% of funding.

Four organisations received external funding against priority 4, including CSIRO, DAFF Qld, DPI NSW and PIRSA (Table 12 & Figure 18). PIRSA received $270,000, representing the majority (44%) of funding against this objective.

For further information on external funding received by each organisation against the RD&E priorities, refer to the organisational summaries (page 103).

Table 12. External investment in biosecurity R&D by national priorities and objectives ($)

	National biosecurity R&D priorities and objectives												
	1A	1B	1C	1D	1E	2A	2B	2C	2D	3A	3B	4	Total
DAFF	430,000	0	0	0	0	0	0	0	0	0	0	0	**430,000**
CSIRO	752,000	650,000	0	740,000	1,833,000	0	1,314,000	0	8,791,000	0	0	90,000	**14,170,000**
DAFF Qld	1,982,431	318,237	0	14,416,931	2,073,288	746,271	7,522,957	288,844	552,663	120,280	82,605	131,770	**28,236,277**
DPI NSW	1,030,000	888,500	0	1,561,000	2,763,000	643,500	4,945,600	15,000	210,000	50,000	410,000	123,000	**12,639,600**
DPI Vic	20,250	795,121	0	0	10,017	40,000	4,685,444	66,771	0	0	0	0	**5,617,603**
ARI Vic	0	0	0	1,286,000	255,000	0	0	0	0	0	0	0	**1,541,000**
PIRSA	906,000	1,300,000	0	343,000	173,000	420,000	3,802,000	370,000	129,000	103,000	10,000	270,000	**7,826,000**
DAFWA	240,000	0	0	0	0	0	0	0	0	320,000	0	0	**560,000**
Fisheries WA	80,000	70,000	0	0	0	0	0	0	0	0	0	0	**150,000**
DPIPWE	160,000	230,000	0	0	475,000	285,000	0	0	0	0	0	0	**1,150,000**
DoR	0	45,000	0	0	0	0	0	0	0	0	0	0	**45,000**
Total	**5,600,681**	**4,296,858**	**0**	**18,346,931**	**7,582,305**	**2,134,771**	**22,270,001**	**740,615**	**9,682,663**	**593,280**	**502,605**	**614,770**	**72,365,480**

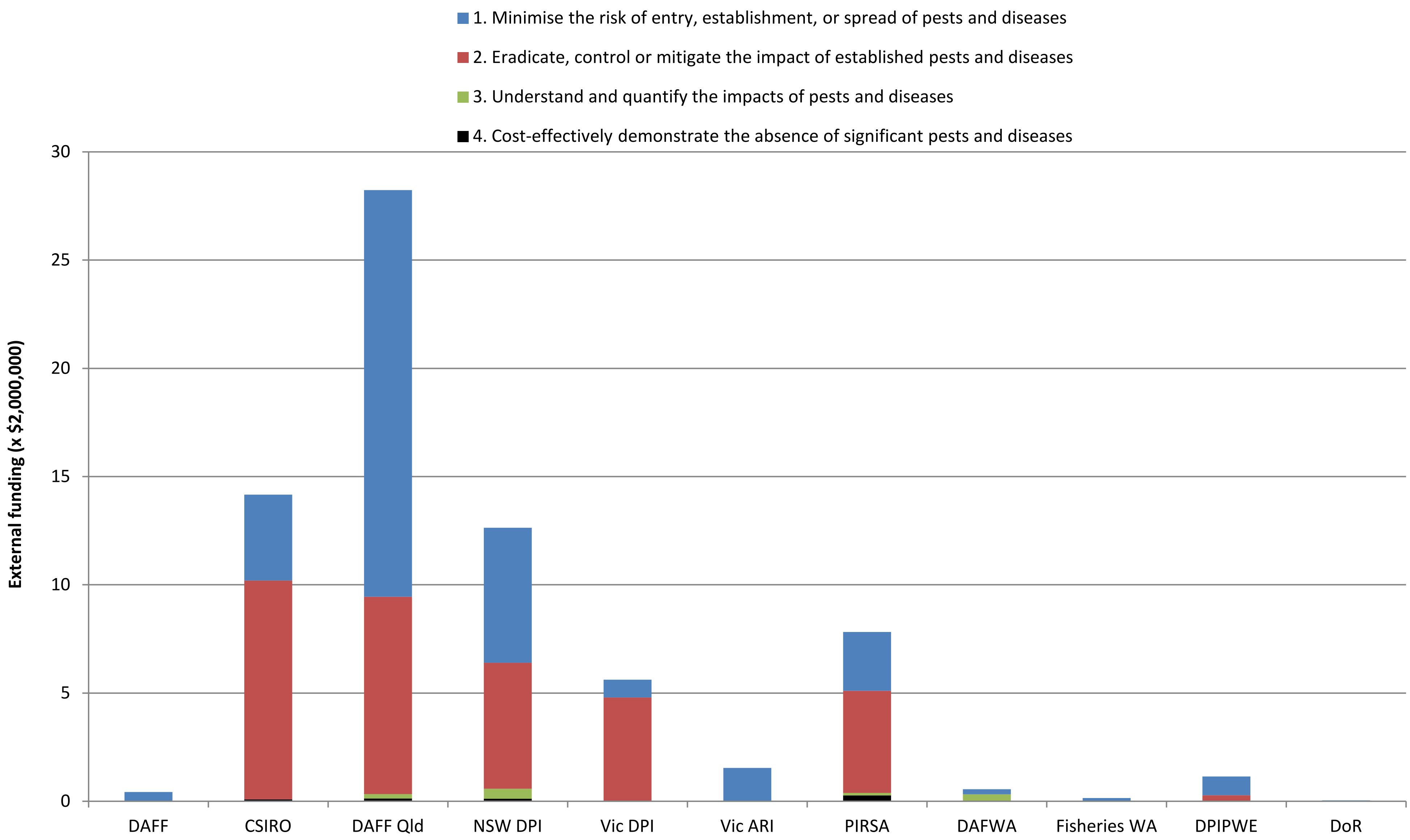

Figure 17. External investment in biosecurity R&D by national priorities (x $1,000,000)

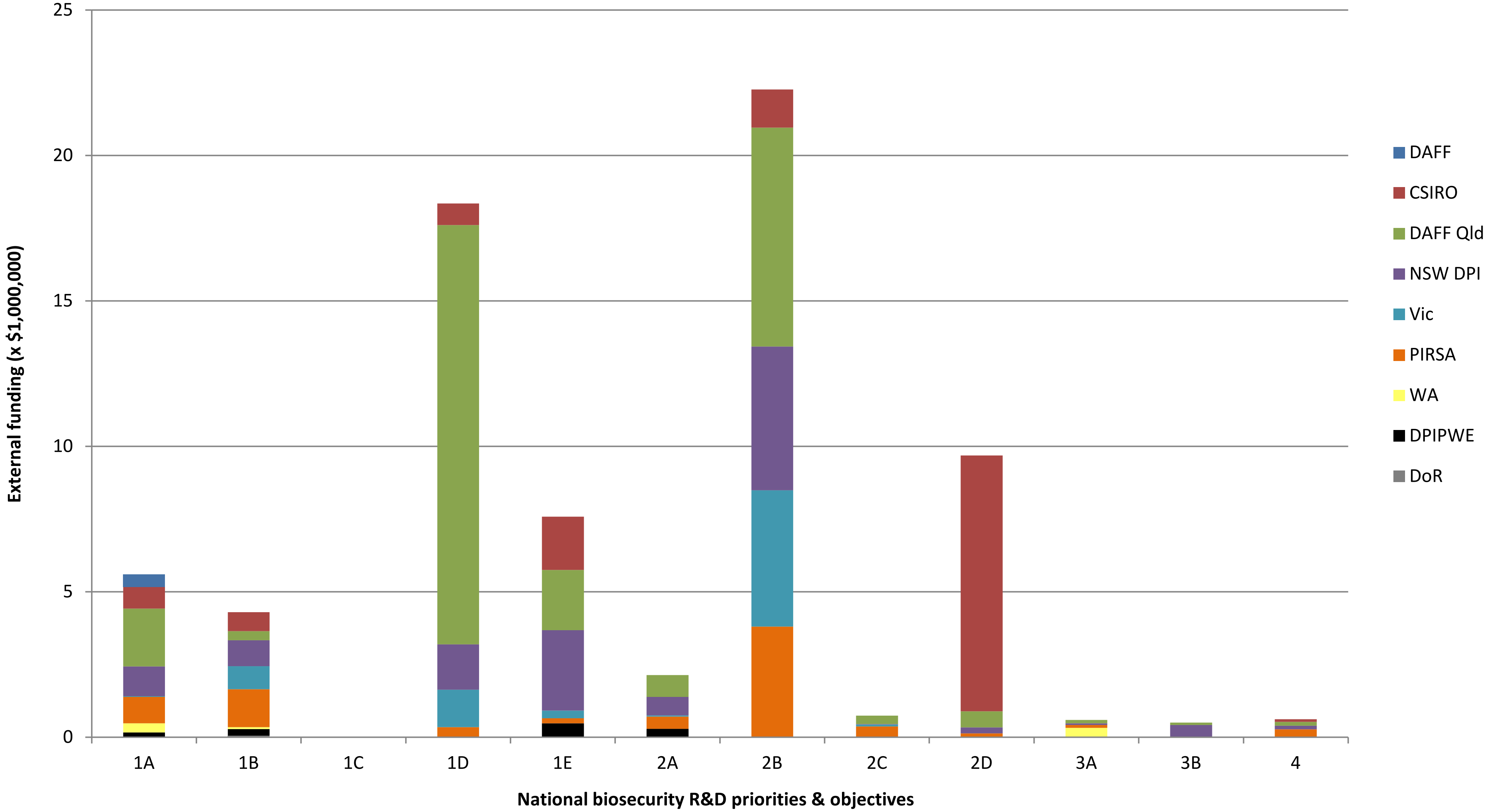

Figure 18. External investment in biosecurity R&D by national priorities and objectives (x $1,000,000)[19]

[19] Data for Vic includes DPI Vic and ARI and data for WA includes DAFWA and Department of Fisheries

3.2.4. External funding – sources

Biosecurity R&D received external funding from many sources as listed in Table 13. For the animal health sector, there were 34 external investors including sources from the Australian Government, state governments, Rural Research & Development Corporations (RDC), industries, universities, commercial and overseas organisations. External investment from these sources went to CSIRO, DAFF Qld, PIRSA, DPI NSW, DPI Vic, DPIPWE and Fisheries WA (Table 13). Rural RDCs, the Australian Government and commercial organisations were the major investors. A large proportion of funding was provided by Meat and Livestock Australia (MLA), the Poultry Cooperative Research Centre (CRC) and MAT. Fisheries Research & Development Corporation (FRDC) funded the greatest number of organisations.

The plant health sector received funding from 37 external investors, including sources from the Australian Government, state governments, Rural Research and Development Corporations (RDC), industries, universities, commercial and overseas organisations (Table 13). External investment from these sources went to seven organisations including CSIRO, DPI NSW, DAFF Qld, PIRSA, DPI Vic, DAFWA and DoR (Table 13). Rural RDCs and the Australian Government were the major investors, with a large proportion of funding provided by the Grains Research and Development Corporation (GRDC), Horticulture Australia Limited (HAL), Grape and Wine RDC (GWRDC), Rural Industries Research & Development Corporation (RIRDC), the Australian Centre for International Agricultural Research (ACIAR), the CRC for National Plant Biosecurity (CRCNPB) and the Cotton Catchment Communities CRC. The CRCNPB, DAFF, GRDC, HAL and GWRDC funded the greatest number of organisations (Table 13).

In contrast to plant health and animal health, the invasive weed species sector received external funding from only 14 organisations, including the Australian Government, state and territory governments, Rural RDCs, the University of Adelaide and an irrigation company (Table 13). External investment went to DPI NSW, DPI Vic, DoR and PIRSA (Table 13). The major investors in this sector were the Rural RDCs (RIRDC and GRDC).

The invasive marine species sector was only externally funded by five organisations, all of which were Australian or state governments (Table 13). Funding was provided to PIRSA, DPI Vic and DPI NSW (Table 13). The greatest proportion of external funding was provided by DAFF.

The invasive animal species sector received funding from 16 sources, including the Australian Government, state government, Rural RDCs, private industry and international sources (Table 13). Funding was provided to NSW DPI, ARI Vic, DAFF Qld and PIRSA (Table 13). The Invasive Animals CRC funded all four organisations, where all other funding bodies provided funds to only one organisation (Table 13).The major investors in this sector were the Australian and state governments, with a large proportion of the funds provided by the Invasive Animals CRC and the Department of Sustainability and Environment (DSE) Victoria.

Almost all the external funding for generic/cross-sectoral R&D went to DAFF Qld, although this is an artefact of the way the investment data was provided. In some cases funding bodies could be clearly allocated to a sector (see Table 13), however others listed under generic/cross-sectoral could be funding for plant health, animal health, invasive weed species or invasive animal species (Table 13). The only other organisation receiving generic/cross-sectoral funding was DAFF, in which external funding was received from all state and territory governments towards BIN (Table 13).

Key issues

- Low number of external funding sources for invasive weed species and invasive marine species and few organisations externally funded in these sectors

Table 13. Sources of external investment

Biosecurity sector	Source of external investment	Organisation (s) receiving funding
Animal health	**Australian Government**	
	Animal biosecurity Cooperative Research Centre (CRC)	CSIRO
	Australian Biosecurity CRC for Emerging Infectious Diseases	DAFF Qld
	Australian Seafood CRC	PIRSA
	DAFF	CSIRO, DPI NSW, DoR
	DAFF Devil Facial tumour Disease Grant	DPIPWE
	Invasive Animal CRC	DPI NSW
	National Health & Medical Research Council (NHMRC)	CSIRO
	Pork CRC	DPI NSW
	Poultry CRC	CSIRO
	State & Territory Governments	
	DAFF Queensland	DPI Vic
	Department of Human Services, Victoria	DPI Vic
	DPIPWE Tasmania (Devil Facial Tumour Disease funds)	DPIPWE
	Fisheries Victoria	PIRSA
	PIRSA Fisheries & Aquaculture	PIRSA
	Rural RDCs	
	Australian Pork Limited	DPI NSW
	Australian Wool Innovation (AWI)	DPI NSW
	FRDC	PIRSA, DPIPWE, DPI Vic, Fisheries WA
	MLA	CSIRO, DPI NSW, DoR

Biosecurity sector	Source of external investment	Organisation (s) receiving funding
	RIRDC	CSIRO, DPI NSW, DoR
	Industry sources	
	Clean Seas Tuna Ltd	PIRSA
	Fishing Industry Associations	PIRSA
	Tasmanian Oyster Industry	DPIPWE
	Tasmanian Salmon Growers Association	DPIPWE
	Universities	
	University of Sydney	DPI NSW
	University of Queensland	DPI NSW
	Commercial funds	
	Centre for Digestive Diseases	DPI NSW
	CSL Limited	CSIRO
	International Animal Health Products	DPI NSW
	MAT	CSIRO
	Pfizer	CSIRO, DoR
	Overseas funds	
	US National Institutes of Health (NIH)	CSIRO
	Other sources	
	Animal Health Australia	DPI NSW
	Hermon Slade Foundation	DPI NSW
	McGarvie Smith Institute	DPI NSW
	Ornamental Fish Management Implementation Group	PIRSA

Biosecurity sector	Source of external investment	Organisation (s) receiving funding
Plant health	**Australian Government**	
	ACIAR	CSIRO, DPI NSW, DoR
	Australian Research Council (ARC)	CSIRO
	Cotton Catchment Communities CRC	DPI NSW, DAFF Qld
	CRCNPB	DPI NSW, DAFF Qld, PIRSA, DPI Vic, DAFWA
	CSIRO	DPI NSW
	DAFF	DPI NSW, DoR, DPI Vic
	Department of Innovation, Industry, Science and Research (DISSR)	CSIRO
	Environmental Trust	DPI NSW
	State & Territory Governments	
	NSW DPI	DPI NSW
	South Australian (SA) Government	PIRSA
	Rural RDCs	
	Bureau of Sugar Experiment Stations (BSES)	DAFF Qld
	Cotton Research & Development Corporation (CRDC)	DPI NSW, DAFF Qld
	GRDC	CSIRO, DPI NSW, PIRSA, DPI Vic
	GWRDC	CSIRO, PIRSA, DPI Vic
	HAL	NSW, PIRSA, DPI Vic, DAFF Qld, DoR
	RIRDC	CSIRO, DPI NSW, DoR

Biosecurity sector	Source of external investment	Organisation (s) receiving funding
	South Australian Grain Industry Trust (SAGIT)	PIRSA
	Industry sources	
	Applied Horticulture Research	DPI NSW
	Australian Sweetpotato Growers Association	DAFF Qld
	Bundaberg Fruit and Vegetable Growers Co-Operative Limited	DAFF Qld
	DuPont	DPI NSW
	Peanut Company of Australia	DAFF Qld
	Phylloxera Board South Australia	DPI Vic
	Plantation Growers	DAFF Qld
	Private Industry	
	Agrochemical firms	DoR
	Universities	
	Charles Sturt University	DPI NSW
	Commercial funds	
	Chevron	DAFWA
	Sunshine Horticultural Service	DAFF Qld
	Overseas funds	
	African Agricultural Technology Foundation	CSIRO
	Finkel Foundation	CSIRO
	Gates Foundation	CSIRO
	The International Maize and Wheat Improvement Center (CIMMYT)	DAFF Qld

Biosecurity sector	Source of external investment	Organisation (s) receiving funding
	Two Blades Foundation	CSIRO
	US Cornell University	CSIRO
	US NIH	CSIRO
	US National Science Foundation	CSIRO
	Miscellaneous	
	Australian Pacific Network (APN)	DPI Vic
Invasive weed species	**Australian Government**	
	Caring for our Country	DPI NSW
	Cotton CRC	DPI NSW
	DAFF (Weeds of National Significance)	DPI NSW
	Department of Sustainability, Environment, Water, Population and Communities (SEWPaC)	PIRSA
	Department of the Environment, Water, Heritage and the Arts (DEWHA) – National Environmental Research Program (NERP)	DoR
	State & Territory Governments	
	Department Sustainability and Environment, Victoria	DPI Vic
	DAFF Qld	DPI NSW
	SA Treasury	PIRSA
	Territory National Resources Management (TNRM)	DoR
	Rural RDCs	
	GRDC	DPI NSW
	RIRDC	DPI NSW, DPI Vic, DoR
	MLA	DoR

Biosecurity sector	Source of external investment	Organisation (s) receiving funding
	Universities	
	University of Adelaide	DPI NSW
	Miscellaneous	
	Irrigation Company	DPI Vic
Invasive marine species	**Australian Government**	
	ARC	PIRSA
	DAFF	PIRSA
	State & Territory Governments	
	Department Sustainability and Environment, Victoria	DPI Vic
	Miscellaneous Government contributions	DPI NSW
	Premier's Science and Research Fund (PSRF)	PIRSA
Invasive animal species	**Australian Government**	
	Caring for our Country	DPI NSW
	DAFF	ARI Vic
	Australian Pest Animal Research Program (APARP) DAFF	DPI NSW
	Invasive Animals CRC	DPI NSW, DAFF Qld, PIRSA, ARI Vic
	Murray Darling Basin Authority (MDBA)	PIRSA
	State & Territory Governments	
	NSW Weeds Program	DPI NSW
	Parks Victoria	ARI Vic
	PIRSA Biosecurity	PIRSA
	SA City council	PIRSA

Biosecurity sector	Source of external investment	Organisation (s) receiving funding
	SA Murray Darling Basin Natural Resource Management Board (SA MDB NRM)	PIRSA
	DPI Vic	ARI Vic
	DSE Vic	ARI Vic
	Rural RDCs	
	AWI	DPI NSW
	MLA	DPI NSW
	RIRDC	DPI NSW
	Private Industry	
	Newmont Mining	DPI NSW
	Other sources	
	International	ARI Vic
Generic/Cross sectoral[20]	**Australian Government**	
	Australian Biological Resources Study (ABRS)	DAFF Qld
	ACIAR	DAFF Qld
	CSIRO	DAFF Qld
	DAFF	DAFF Qld
	DEWHA	DAFF Qld
	Fire Ants	DAFF Qld

[20] Majority of external funding information for this sector provided by DAFF Qld and may include sources of investment for animal health, plant health, invasive weed species or invasive animal species

Biosecurity sector	Source of external investment	Organisation (s) receiving funding
	State & Territory Governments	
	All state and territory governments	DAFF (Biosecurity Information Network)
	Brisbane City Council	DAFF Qld
	DAFWA	DAFF Qld
	DPI Vic	DAFF Qld
	Fire Ants - States	DAFF Qld
	DPI NSW	DAFF Qld
	PIRSA	DAFF Qld
	Rural RDCs	
	RIRDC	DAFF Qld
	GRDC	DAFF Qld
	MLA	DAFF Qld
	Universities	
	University of Queensland	DAFF Qld
	University of Southern Queensland	DAFF Qld
	University of Tasmania	DAFF Qld
	University of Western Australia	DAFF Qld
	Commercial funds	
	Fitzroy Basin Association Incorporated	DAFF Qld
	The Northern Gulf Resource Management Group	DAFF Qld
	Other	DAFF Qld

Biosecurity sector	Source of external investment	Organisation (s) receiving funding
	Miscellaneous	
	Queensland Alliance for Agriculture and Food Innovation	DAFF Qld

3.3. Infrastructure

3.3.1. Infrastructure investments

Data was collected for infrastructure investments for the past five years (2007 – 2011) and the next five years (2012 – 2016). Infrastructure investments for the past five years totalled $769,012,860 (Table 14). Some of the major investments included capital upgrades to Australian Animal Health Laboratory (AAHL) Geelong, valued at $32 million, development of the Ecosciences Precinct[21] (Dutton Park, Brisbane) and the Health and Food Sciences Precinct[21] (Coopers Plains, Brisbane), valued at $259.5 million and $101.3 million respectively, biosecurity upgrade of the Elizabeth Macarthur Agricultural Institute (EMAI) at Menangle, NSW, valued at $57 million and development of the Centre for AgriBioscience[22] (AgriBio), located at La Trobe University's Bundoora campus, valued at $288 million (Table 14).

Other significant investments for the past five years included support of AAHL through the National Collaborative Research Infrastructure Strategy (NCRIS), valued at $12.5 million, development of the DPI NSW Central Coast Primary Industries Centre, valued at $8.5 million and development of the South Australian Aquatic Biosecurity Centre, valued at $2.6 million (Table 14). In addition, DPI Vic listed a number of priceless investments including a database of distribution maps of marine exotics, Bioweb, a web based emergency response and surveillance platform, and various taxonomic collections housed at Bundoora (Table 14 and for further information on taxonomic collections see DPI Vic summary, page 128).

Infrastructure investments forecast for the next five years (2012 – 2016) totalled $20,410,000 (Table 14). This represents significantly less than the investments for the past five years. Key infrastructure investments included the development of the Tropical Biosecurity Laboratory[23] at James Cook University, Townsville, valued at $17 million and continued development of the Central Coast Primary Industries Centre valued at $2 million (Table 14). Other significant investments included a QC3 room upgrade for DoR valued at $0.5 million, continued development of the South Australian Aquatic Biosecurity Centre, valued at $0.4 million, upgrades to the Robert Wicks Pest Animal Research Station at Inglewood valued at $180,000 and development of a Resource Management Package by DAFF, valued at $150,000 (Table 14).

Key issues

- In the past five years there has been a large investment in infrastructure. However there is a need for adequate capability building and provision of long term career structures so we have the future capacity to utilise this infrastructure. In addition, a future challenge will be to maintain this infrastructure.

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[21] Note that this infrastructure was a joint venture between the Queensland Government and CSIRO and is not solely utilised for biosecurity R&D purposes

[22] Note that this infrastructure was a joint venture between the Victorian Government and La Trobe University

[23] Development of this facility has been scrapped

Table 14. Infrastructure investments for the last 5 years (2007 – 2011) and forecast for the next 5 years (2012 – 2016)

	2007 - 2011			2012 - 2016		
	Name of infrastructure	**Location**	**Value**	**Name of infrastructure**	**Location**	**Value**
DAFF	BioSIRT software application	Australian Government	$1,150,860	Resource Management Package	Australian Government	$150,000
CSIRO	AAHL Capital upgrades	Geelong	$32,000,000			
	NCRIS	Geelong	$12,500,000			
DAFF Qld	EcoSciences Precinct	Dutton Park, Brisbane	$259,500,000	Tropical Biosecurity Lab	Townsville	$17,000,000
	Health and Food Sciences Precinct	Coopers Plains, Brisbane	$101,300,000	Robert Wicks Pest Animal Research Station	Inglewood	$180,000
	Robert Wicks Pest Animal Research Station	Inglewood	$900,000			
	Laboratory Information Management System (LIMS)		$1,300,000			
DPI NSW	Biosecurity upgrade EMAI	Menangle, NSW	$57,000,000	Continued development of Central Coast Primary Industries Centre	Gosford	$2,000,000
	Central Coast Primary Industries Centre	Gosford	$8,500,000			
	Greenhouses	Wagga Wagga Agricultural Institute	$900,000			

	2007 - 2011			2012 - 2016		
	Name of infrastructure	Location	Value	Name of infrastructure	Location	Value
DPI Vic	Marine – 'Walkan'[24]	Queenscliff	$150,000			
	Marine – other vessels and equipment[25]	Queenscliff	$500,000			
	Marine - Database of distribution maps of exotics	Queenscliff	Priceless			
	Plants/animals - Bioweb web based emergency response and surveillance platform	Attwood/Bendigo	Priceless			
	AgriBio (20,000m^2 building, 3,000 m^2 glasshouses) as surge capacity for biosecurity	Bundoora	$288,000,000			
	Taxonomic collections	Bundoora	Priceless			
	Dedicated AQIS accredited glasshouse and post entry quarantine facility	Horsham				
	QC 2 laboratory upgrade	Horsham	$50,000			

[24] Walkan is an 8 m twin-hulled SharkCat with associated field equipment to support SCUBA divers and technicians in in-shore and near-shore marine waters

[25] Used for tracking and monitoring fish (exotics), as well as facilities (tanks, laboratories) used for experimental purposes which can be, and have been, used for biosecurity research in both fresh and marine waters

	2007 - 2011			2012 - 2016		
	Name of infrastructure	Location	Value	Name of infrastructure	Location	Value
PIRSA	South Australia (SA) Aquatic Biosecurity Centre	Roseworthy Campus	$2,600,000	SA Aquatic Biosecurity Centre	Roseworthy Campus	$400,000
	Molecular Diagnostics laboratory	Waite Campus	$1,700,000	Quarantine Insectary Upgrade	Waite Campus	$50,000
				Post-Entry Plant Quarantine Upgrade	Waite Campus	$50,000
Fisheries WA	Animal health - Laser microdissection microscope	South Perth	$100,000	-80^{o}C freezer	South Perth	$30,000
	Animal health - Real-time PCR machine	South Perth	$30,000	Marine - Molecular laboratory facilities	Perth	$50,000
	Marine – Molecular laboratory facilities	Perth	$100,000			
DPIPWE	Aquarium Facility for vaccine research	Launceston	$130,000			
	AB 7500 RTPCR & Associated Equipment	Launceston	$170,000			
DoR	PCR clean room	DoR	$104,000	QC3 room upgrade	DoR	$500,000
	UPS power points	DoR	$4,000			
	BMS computer upgrade	DoR	$24,000			

3.3.2. Key national biosecurity R&D infrastructure

Organisations were asked to list key national biosecurity R&D infrastructure. DAFF identified the Australian National Insect Collection, Australian National Herbarium and Australian Museum as key infrastructure and both CSIRO and PIRSA identified AAHL (Table 15). DAFF Qld identified the Robert Wicks Pest Animal Research Station and DPI NSW listed the Domestic Animal Pathology Registry, Australian Scientific Collections Unit and EMAI QC2 and QC3 labs as key biosecurity R&D infrastructure. PIRSA identified the South Australian Aquatic Biosecurity Centre, Australian Experimental Stockfeed Extrusion Centre and Waite Insect and Nematode Collection as key infrastructure and DPIPWE identified the Animal Health Laboratory (AHL), Australian Biosecurity Information Network (ABIN) Vetpath Node, AHL Bacterial Culture Collection and the Devil Face Tumour Disease (DFTD) Bacterial Artificial Chromosome (BAC) Library, all located in Launceston, as the key national biosecurity R&D infrastructure (Table 15). Further information on key national biosecurity R&D infrastructure can be found in the responses to the qualitative survey (page 92).

Table 15. Key national biosecurity R&D infrastructure identified by organisations

Organisation	Name of infrastructure	Location
DAFF	Australian National Insect Collection	Canberra
	Australian National Herbarium - Centre for Australian National Biodiversity Research	Canberra
	Australian Museum	Sydney
CSIRO	AAHL	Geelong
DAFF Qld	Robert Wicks Pest Animal Research Station	Inglewood
DPI NSW	Domestic Animal Pathology Registry	EMAI
	Australian Scientific Collections Unit	Orange
	EMAI - QC2 and QC3 labs	EMAI
PIRSA	AAHL	Geelong, Victoria
	South Australia (SA) Aquatic Biosecurity Centre	Roseworthy Campus, SA
	Australian Experimental Stockfeed Extrusion Centre	Roseworthy Campus, SA
	Waite Insect and Nematode Collection	Waite Campus
DPIPWE	Animal Health Laboratory (AHL)	Launceston
	ABIN Vetpath Node	Launceston
	AHL Bacterial Culture Collection	Launceston
	Devil Face Tumour Disease (DFTD) BAC Library	Launceston

3.4. Qualitative survey – national focus

As part of the capability audit, a qualitative questionnaire was designed to capture expert opinion of researchers and biosecurity policy makers and data not able to be captured quantitatively. Some questions have been included in the organisational summaries as they are internally focussed and relate to areas of expertise, international partnerships and future investment direction. The remainder of the survey is reported here and captures information on key national biosecurity R&D infrastructure, key capability that is vulnerable or at risk, emerging issues and emerging and potential capabilities for biosecurity R&D and opinion on where Australia should invest more heavily into the future.

3.4.1. Animal health

Australia's key national resources in biosecurity R&D in animal health are considered to be:

- AAHL, Geelong (including the "National Biosecurity" Aquatic Animal Health Laboratories)
- Centre of Advanced Animal Science
- Department of Agriculture, Food and Fisheries
- Sheep CRC (based in Armidale NSW)
- Queensland DPI for toxicology and residue research
- The SA Aquatic Biosecurity Centre, Roseworthy Campus, South Australia
- Regional vet labs
- ABIN
- Professional societies
- Animal Health Australia
- National Biosecurity Flagship
- Unique knowledge and experience of the Berrimah Veterinary Laboratory (BVL) arbovirus team
- BVL arbovirus isolate collection – a very large and significant collection which is most valuable arbovirus collection in Australia
- BVL arbovirus serum bank – the most important of this type in Australia
- Trained people – veterinarians, pathologists, epidemiologists, biometricians etc. and experts in relevant areas of biosecurity (disease, food safety), CSIRO, state researchers, university researchers
- Existing networks (e.g. FRDC Subprogram of Aquatic Animal Health, Subcommittee on Aquatic Animal Health and NEPTUNE)

Key national biosecurity R&D capability that is particularly vulnerable includes:

- Small and ageing pool of expertise in a number of areas, e.g. pathologists, microbiologists and associated disciplines in Australia
- Loss of northern Australia arbovirus knowledge through retirement of staff
- Difficulty in recruiting skilled researchers, veterinarians and pathologists to the Northern Territory
- The lack of succession planning of scientists to underpin our standard setting in the general area of biosecurity
- Multiple facilities working in this area and the lack of any national coordinated approach to facility needs and management

- The One Health approach that needs coordinated resourcing and structure
- All government funded entities (Universities, state and commonwealth departments of agriculture and ABIN) which are under significant financial pressure due to reduction in funding or no ongoing funding (ABIN)
- Marine Taxonomy – Australia wide - ageing workforce that is not being replaced and is generally poorly supported (FRDC review about to be initiated following recommendation by the Fisheries & Aquaculture, National Research Providers Forum)
- Lack of socio-economic research in association with aquatic biosecurity

Emerging issues that need highlighting to decision makers include:

- The increasing risk from new and emerging diseases of wildlife, livestock and man
- The effects of climate change on the risks of these diseases emerging
- Under-reporting of livestock disease
- The need for a "one health" approach
- The need to have a nationally coordinated approach (through the National Biosecurity Flagship)
- Loss of capability, coupled with inadequate funding to enable mentoring and transfer of knowledge to new staff
- Shortage of skilled biosecurity personnel outside major cities
- Biosecurity R&D (as in all government related activities) must contend with declining resources, and the management of human resources through succession planning and staff retention incentives
- Animal welfare is impacting on how research can now be done, and is a significant cost component of research activities
- In the aquatic area almost all diseases are new and emerging native animal diseases for which there is/will be no overseas research or investment, but which generate trade issues. The R&D has to come from within Australia.
- Lack of a funding body to support R&D on freshwater pests (includes ornamental fish industry)
- Shrinking funding for RD&E on aquaculture & fisheries due to the current economic environment. Despite many industry sectors recognising the need for proactive R&D in this field, currently having aquatic animal health issues, and new issues often with considerable potential for negative economic impact arising regularly without warning.
- Lack of employment opportunities for R&D specialists in aquaculture & fisheries despite increased veterinary education and training generating more potential employees

Potential and/or emerging capabilities which could be applied to biosecurity include:

- Bioinformatics
- Modelling of disease outbreaks and prediction
- RNAi technology for a range of science issues
- Live cell imaging
- The underpinning sciences
- Discovery and development of disease resistant animals

- ABIN or similar as an information sharing and communication tool (these are likely to be significantly enhanced as access to the NBN becomes more widespread)
- High throughput sequencing
- Micro-arrays
- The application of mobile phone technology to improve surveillance data gathering, and to monitor livestock movements (i.e. Automated movement system based on mobile phone linkages)
- Advances in molecular biological techniques and Matrix-assisted laser desorption/ionisation-time of flight mass spectrometry (MALDI-TOF MS). MALDI-TOF MS has been used for bacterial identification but has wider application for detection of other infectious agents, chemicals, residues and proteins.
- Encouraging more take-up of aquatic RD&E by existing terrestrial biosecurity personnel and organisations
- More rapid application of novel technologies from terrestrial to aquatic fields
- South Australia has the opportunity to further develop its biosecurity capability in managing pests and diseases with the use of therapeutic feeds through further integration of SARDI's and the Universities livestock, including fish, nutritional and aquatic animal health capabilities aligned to the Veterinary School, University of Adelaide and the Australasian Experimental Stockfeed Extrusion Centre, SARDI. Both are nationally unique, multi-million dollar facilities at the Roseworthy Campus, Uni of Adelaide and those involved also have comprehensive stock - diet evaluation facilities as well. Marine Innovation South Australia (MISA) provides an ideal "vehicle" for pursuing this alignment in the aquatic field.
- South Australian Research and Development Institute (SARDI) might further develop its selective breeding/genetics/molecular techniques capability in the area of biosecurity, policy and compliance, unique niches where competition with CSIRO would be less than in the production area (growth rate and market characteristics).

Australia should invest more heavily in biosecurity R&D in:

- Emerging threats and exotic pathogens that threaten Australia. The priorities are being set by a separate exercise and this will provide a national framework to guide our investments in this area
- Staff mentoring
- Enhanced diagnostics – to enable test improvement, development of more specific tests and sorting out problems with some of the older tests
- Surveillance as we need a nationally acceptable, simple, effective surveillance system, with trained people in strategic locations to make it work. In particular there is a need to increase regional/early warning surveillance – for example arbovirus monitoring used to encompass a wider range of animal species than in the past which would potentially increase the likelihood of detecting new arboviruses – this sort of work should be reinstated. In addition, increased disease surveillance to support market access.
- Investment should be targeted to both institutions and individuals to encourage professional and organizational engagement. For example, the Australian biosecurity CRC provides a vehicle to fund PhD scholarships and financial support of talented graduates.

- Laboratory networking initiatives such as the Laboratories for Emergency Animal Disease Diagnosis and Response' (LEADDR) program to enable more or improved lab networking which will facilitate greater consistency, sharing of increasingly limited specialised expertise and reduction of duplication. The extension of the LEADDR program through AAHL is encouraged. This initiative will expand the emergency animal disease (EAD) response capability by providing training, reagents and standardization of EAD tests to jurisdictions in the event of an EAD.
- There is a need to link biosecurity more strongly with the national food security plan, and a need to boost the value of biosecurity in its fullest sense, in the minds of politicians.
- Biosecurity R&D needs to be prepared for the future, without forgetting the past. New and emerging diseases (Hendra, Nipah, Severe Acute Respiratory Syndrome - SARS, avian influenza) will continue to occur, and probably at an increasing rate due to changes in human, animal, wildlife and environmental interactions due to population increase, urbanization and climate change. The re-emergence of significant diseases could also re-occur due to changes in animal husbandry and welfare consideration that have led to de-intensification of animal farming systems. Meeting these challenges will require a robust and capable front line disease surveillance system, backed by a responsive R&D capability funded through best practice infrastructure and staff by capable, trained and committed teams.
- The RD&E required to increase the availability and effective use of therapeutics for the management of the pests and diseases of aquaculture
- Marine and freshwater invasive species affecting aquaculture
- Coordination of a national laboratory network for animal health diagnostics (following the successful model currently being established in plant biosecurity)

3.4.2. Plant health

Australia's key national resources in biosecurity R&D in plant health are considered to be:

- Australian Plant Pest Database (APPD)
- Cereal germplasm collections
- Cereal pathogenomics database being developed under BPA auspices
- Grains industry cereal rust control program
- CRCNPB
- Plant Health Australia
- Australian National Insect Collection and state-based museums and associated collections
- Australian National Herbarium and state-based herbaria and associated collections
- Plant Pathology Herbarium
- Pest and Disease Image Library (PaDIL)
- Australian Faunal Directory
- Atlas of Living Australia (ALA)
- Flora of Australia Online
- Integrated Biodiversity Information System
- Centre for Australian National Biodiversity Research

Key national biosecurity R&D capability that is particularly vulnerable includes:

- Virology research capability – limited number of researchers distributed across multiple agencies and lack of training
- Nematode research capability – very limited number of researchers distributed across few agencies and lack of training
- Pathology and entomology as there is a lack of training in these disciplines
- Plant protection specialists as their numbers are diminishing Australia wide
- Termite research as DoR is currently the only government agency in Australia working on termites
- Taxonomic expertise - specifically acarology, nematology and bacteriology. There is little expertise in Australia and although these skills are needed only intermittently they are important for market access and for accurate identification in incursions. It is important that taxonomists are well-linked to international networks and are using a range of techniques including molecular approaches.
- The ageing expertise in biosecurity R&D. In addition, many experts, especially in the plant area, are only accessible on occasion as they are retired with no replacement expertise in Australia.

Emerging issues that need highlighting to decision makers include:

- The potential incursion of new plant specific pests and diseases, especially in the cereals, wine and sugar industries
- The potential for evolution of novel fungal diseases thru genome fusion as occurring in USA and Europe with regard to Phytophthoras
- The escalating rate of the discovery of new plant micro-organisms (that may or may not cause disease) revealed by second generation gene sequencing technologies
- Chemical pesticide withdrawal e.g. methyl bromide, fenthion, dimethoate etc.
- Studies are required to support market access
- The need for environmental agency engagement on pest risk assessment
- The need for studies to support pest risk assessment
- Low student participation and recruitment in areas of importance to biosecurity
- Educational institutes need to continue to train plant protection professionals
- Lack of researchers with general pathology and entomology capability
- Ageing workforce

Potential and/or emerging capabilities which could be applied to biosecurity include:

- New developments in bioinformatics knowledge, skills and technologies
- Molecular diagnostics, particularly for insects systems approaches
- Biosensor technology which offers exciting potential but new technologies must be balanced with broader training in core areas of pathogen, pest and weed identification and biology

Australia should invest more heavily in biosecurity R&D in:

- Protecting the nation's major export oriented agricultural industries (grains, wine, sugar, cotton) from existing threats
- Avoiding incursions and mitigating the impact of any new incursions
- Capacity building
- Australians working overseas

- Semiochemistry (field management of pests and detection of exotics)
- More focus on priority commodities, as determined by government and industry
- Recent specialised workshops to improve skills in identification of key pests and pathogens e.g. rust identification are an excellent initiative and should be continued
- Efforts to coordinate biosecurity R&D via Plant Biosecurity CRC and National Diagnostic Network are extremely helpful
- Improved industry training and linkages in biosecurity R&D affecting market access

3.4.3. Invasive weed species

Australia's key national resources in biosecurity R&D in invasive weed species are considered to be the Weeds CRC (now finished) and the National Weeds and Productivity Research Centre.

Key national biosecurity R&D capability that is particularly vulnerable includes R&D in biological control of weeds as this area is difficult to attract funding towards.

Emerging issues that need highlighting to decision makers include the lack of joint planning and strategy development by researchers and biosecurity managers (government and industry). As an example for weeds – there is a rapid proliferation of research projects that produce outputs that are impractical for application by biosecurity agencies e.g. eradication feasibility studies using detailed life history data that is difficult and costly to obtain and takes many years to collect. By the time the data is collected, the species being assessed is beyond eradication and could have been controlled for less money than obtaining the data.

Potential and/or emerging capabilities which could be applied to biosecurity include social sciences for understanding factors significant to adoption of responsibility for managing weeds, and for adoption of best practice.

Australia should invest more heavily in the biosecurity threat from existing weeds already in Australia. Reducing the impact and spread from existing weeds will produce significant benefits to both the environment and sustainable agricultural production. As such, there is a high public good component to R&D in this area and significant cross-sectoral benefits to be gained from research outcomes. It is an area where there is the potential for significant overlap in R&D activities without leadership and clear direction.

3.4.4. Invasive marine species

Australia's key national resources in biosecurity R&D in invasive marine species are considered to be fisheries, aquaculture, environment and commerce.

Key national biosecurity R&D capability that is particularly vulnerable includes:

- Specialist taxonomic expertise as specialists are few and far between, and a lack of succession planning with regard to taxonomic training
- Lack of a 'representative' body to link or coordinate research to avoid replication and encourage national collaborations
- Lack of socio-economic research in association with aquatic biosecurity

Emerging issues that need highlighting to decision makers include:

- Lack of capacity to identify potential pests based on lack of taxonomic skill
- Paucity of molecular data
- Lack of understanding of native species and thus what constitutes a potential pest

- Risks posed by increasing anthropogenic activity
- The lack of a ‘representative’ body to link or coordinate research to avoid replication
- Lack of funding for R&D to support the recently released Biofouling Strategy
- Lack of funding for R&D to maximise the use of existing specialised facilities
- Lack of a funding body to support R&D on marine pests (includes ballast waters)

Potential and/or emerging capabilities which could be applied to biosecurity include:

- Molecular ID based on barcoding
- Real-time PCR detection of planktonic pest species
- Next generation sequencing for environmental sampling
- Shellfish selective breeding and associated technologies - an innovative project to manage invasive Pacific oysters through selective breeding was submitted to Biosecurity SA, although it was not funded. The use of selective breeding and the development of triploids, double haploids and single sex stock populations all offer mechanisms to enhance biosecurity (as well as protect Intellectual Property).

Australia should invest more heavily in biosecurity R&D in:

- National taxonomic training and national coordination of research to avoid duplication and encourage national collaborations
- Marine invasive species

3.4.5. Invasive animal species

Australia’s key national resources in biosecurity R&D in invasive animal species are considered to be:

- Research staff (including remnant scientific staff in state agency research groups), their knowledge and the information that they generate
- Invasive Animals CRC

Key national biosecurity R&D capability that is particularly vulnerable includes:

- Rabbit researchers due to a lack of succession planning, in particular those working on rabbit ecology as about 70-80% of national expertise is over 55 years old
- Entomology staff as there are few training options for entomology and it is possible that this area of expertise will be deficient in the future
- Pest bird ecology; all state agency expertise >55yo, nationally no others still currently working in R&D other than 1 PhD on starlings Mouse plagues; all national expertise over 55 years old, no others still currently working in R&D
- Biocontrol research – ageing expertise, low capacity to fund long term research programs over more than one budget cycle

Emerging issues that need highlighting to decision makers include:

- The unfolding incursion of foxes in Tasmania
- The proliferation of rabbits post Rabbit Haemorrhagic Disease
- Invasive spread modelling, especially for species, is difficult to detect
- Biological control research is long-term, usually requiring time-lines of >10 years, so cannot be done effectively with ad-hoc funding

Potential and/or emerging capabilities which could be applied to biosecurity include:

- Social sciences for understanding factors significant to adoption of responsibility for managing pest animals, and for adoption of best practice
- Economics linked to impact and risk assessment
- Consistent and efficient information, data and knowledge management

Australia should invest more heavily in biosecurity R&D in:

- The detection of new incursions and eradication of early infestations, especially those in remote or difficult areas
- The long-term funding of biological control programs, including monitoring of field effectiveness. Lack of long-term funding commitment to R&D programs makes it impossible to attract, train and retain highly capable staff. The funding model for CRCs has not worked in this respect – to our knowledge, only 1 person that began their pest animal R&D with the 14-year Pest Animal CRC remains in the field. Much corporate knowledge in pest animal R&D was lost when CSIRO Division of Wildlife and Ecology gradually moved out of pest animal R&D and ultimately disbanded. State agencies have been gradually contracting in this area for > 10 years and more than 80 % of remaining national corporate knowledge will be lost within another 10 years as staff retire. Universities are filling some of the void in research (e.g. in CRCs) but their staff tend to be highly mobile, both in their physical location and research interests, and seldom provide repositories of long-term corporate knowledge.

Other comments:

- Reducing the impact and spread from existing weeds and pest animals will produce significant benefits to both the environment and sustainable agricultural production. As such, there is a high public good component to R&D in this area and significant cross-sectoral benefits to be gained from research outcomes. It is an area where there is the potential for significant overlap in R&D activities without leadership and clear direction.

3.4.6. Generic/Cross-sectoral

Australia's key national resources in biosecurity R&D that are generic/cross-sectoral are considered to be:

- Reference collections – type specimens of fungi, insects, viruses, bacteria etc, e.g. Australian National Insect Collection and state based museums and associated collections
- EMAI (NSW)
- AgriBio
- Australian Virtual Herbarium, National Herbarium and state based herbaria and associated collections
- Atlas of Living Australia
- AQIS Import Conditions Database
- Australian Biosecurity Intelligence Network
- Ecosciences precinct, CSIRO, Queensland
- National laboratory network
- National bioinformatics services
- National QC3/PC3 compliant laboratory capacity
- Australian Centre for International Agricultural Research (ACERA)

Key national biosecurity R&D capability that is particularly vulnerable includes:

- The ageing expertise in biosecurity R&D in all sectors nationally. Most research leaders are over 50 years old and many over 60 years old. In addition, many experts, are only accessible on occasion as they are retired with no replacement expertise in Australia. Specific vulnerabilities include:
    - Nematode taxonomy (1 national expert >55yo, difficult to attract funding)
    - Bacterial taxonomy (no national experts, difficult to attract funding)
    - Fungal taxonomy (few in number, most >55yo, difficult to attract funding)
    - Invertebrate taxonomy (most >55yo, difficult to attract funding)
- Additional vulnerabilities include retention and advancement of female scientists into senior research and leadership positions.

Emerging issues that need highlighting to decision makers include:

- The lack of joint planning and strategy development by researchers and biosecurity managers (government and industry).
- Lack of skilled staff in government who can analyse and interpret quantitative data when it is available.
- Antibiotic and chemical resistance
- The need for much more work on the social aspects that affect biosecurity issues. For example, the need to gain community support across a range of sectors and sometimes conflicting agendas.
- A general lack of fundamental biological research, primarily because this generally does not attract funding from any source
- In the current challenging economic environment, the scattered and often individual based nature of biosecurity capability in Australia is likely to result in loss of capacity and expertise
- The negative consequences of an increasing focus by national funding bodies on reactive applied R&D as against a balanced portfolio of this and proactive, and pure and blue-sky R&D
- Failure of all levels of government and natural resource management to effectively fund and resource their policy and legislative responsibilities.
- Declining funds in natural resource management programs such as Natural Heritage Trust, Caring for our Country etc.
- Lack of effective pest response plans and protocols
- Infrastructure Costs: The high costs of compliance and maintenance of high containment laboratories, animal houses and greenhouses is potentially unsustainable. Experience nationally and internationally indicates required maintenance budgets are more than ten times higher than on the infrastructure that has been replaced. This is extremely challenging given the fiscal contraction being experienced in all government jurisdictions. This may lead to increased risk of biosecurity breach as a result of R&D activities.
- Funding uncertainty: When the development of the Animal Biosecurity and Plant Biosecurity Strategies under the PISC RD&E Framework is complete, their effective implementation will rely on the ability to secure funding from relevant RDCs. The Commonwealth needs to ensure that the funding environment acknowledges the comprehensive sectoral and cross sectoral priority setting role undertaken by all PISC agencies in the context of the Framework’s development. This would be best

achieved by ensuring reasonable alignment between Strategy priorities and the criteria applied by Commonwealth-funded RDCs in granting project funding, thereby providing a reliable platform for the long term engagement of research partners, investment in infrastructure and the development and retention of expertise. Funding uncertainty also arises where future R&D expenditure is difficult to forecast in circumstances where there may be expanding geographic distribution of serious threats, for example due to climate change, natural selection, urbanisation, with a need for a shift in R&D focus to combat these threats (e.g. Qld Fruit Fly)

Potential and/or emerging capabilities which could be applied to biosecurity include:

- New statistical and numerical tools for analysing complex surveillance data collected (perhaps) haphazardly in space and time (i.e. Approximate Bayesian Computation – ABC)
- DNA Barcoding – using genetic techniques to inform incursion management by determining whether new incursions originate from known infestations or from new sources
- Semiochemical lures and electronic noses for surveillance
- Remote microscopy to connect expert to specimen
- The ability to digitise and store millions of data points
- Smart phones, tablets, apps and citizen science
- Real-time animal health monitoring
- Social networking for information flow
- Risk assessment and broad based (or community based) cost benefit analysis as applied to the assessment of biosecurity risks
- Bioinformatics
- Pest and pathogen evolution – changing pressures due climate change, diversity of native hosts and vectors
- Forensic science
- Citizen science techniques and emerging underpinning IT tools
- Natural resource management landscape scale planning and remote sensing and monitoring tools and techniques

Australia should invest more heavily in biosecurity R&D in:

- Investment in training public servants in risk analysis and structured decision making
- Better strategies for management of established pest species
- Understanding where investment in biosecurity activities is currently allocated across the national biosecurity continuum (not just R&D)
- Risk assessment, economic analysis, spatial modelling and visualisation to better guide policy and investment allocation decision making
- Adaptation or development of new technology to collect, analyse and communicate biosecurity data
- Cost-effective diagnostic and surveillance tools
- Social research to better engage and involve regional, urban and remote communities in biosecurity agencies
- Social research to better engage regulatory authorities with local industry and local governments

- Diagnostics for high through analysis for multiple pathogens using suspension array type assay
- Bio-Informatics and digitisation of pathogens and invasive pests for rapid identification
- Remote sensing for identification and delimitation of pest or disease incursion
- Basic biological research associated with key species of interest (e.g. economically important ones), their environment and the epidemiology of pest and diseases of potential concern
- Long-term/permanent positions for research staff in order to enable ongoing engagement with pest species research and management

3.4.7. Environmental biosecurity

Australia's key national resources in environmental biosecurity are considered to be:

- Ecosciences precinct, CSIRO, Queensland
- Natural Resource Management Boards
- Murray-Darling Basin Authority and Native Fish Strategy
- Lake Eyre Basin Ministerial Forum

Key national biosecurity R&D capability that is particularly vulnerable includes:

- Small number of researchers in general
- No succession planning
- Those working in epidemiology of wildlife disease

Emerging issues that need highlighting to decision makers include:

- Recent reduction of funding by DAFF to the Australian Wildlife Health Network that will result in a major reduction in wildlife health investigations throughout Australia. This is of concern given the number of recent emerging diseases that have occurred in wildlife.
- Declining funds in natural resource management programs such as Caring for our Country etc.

Australia should invest more heavily in biosecurity R&D in:

- Avoiding incursions and mitigating the impact of any new incursions. There is very little effective spend on diseases (especially invasive ones) of native systems (e.g. Myrtle rust).
- Protection of native biodiversity

4. Organisational Summaries

4.1. Department of Agriculture, Fisheries and Forestry

4.1.1. Human Capability

The Department of Agriculture, Forestry and Fisheries (DAFF) employs a total of 95.7 FTEs in biosecurity R&D across the biosecurity sectors (Figure 19). All sectors were represented, with plant health containing the largest capability (57%) of the sectors (Figure 19).

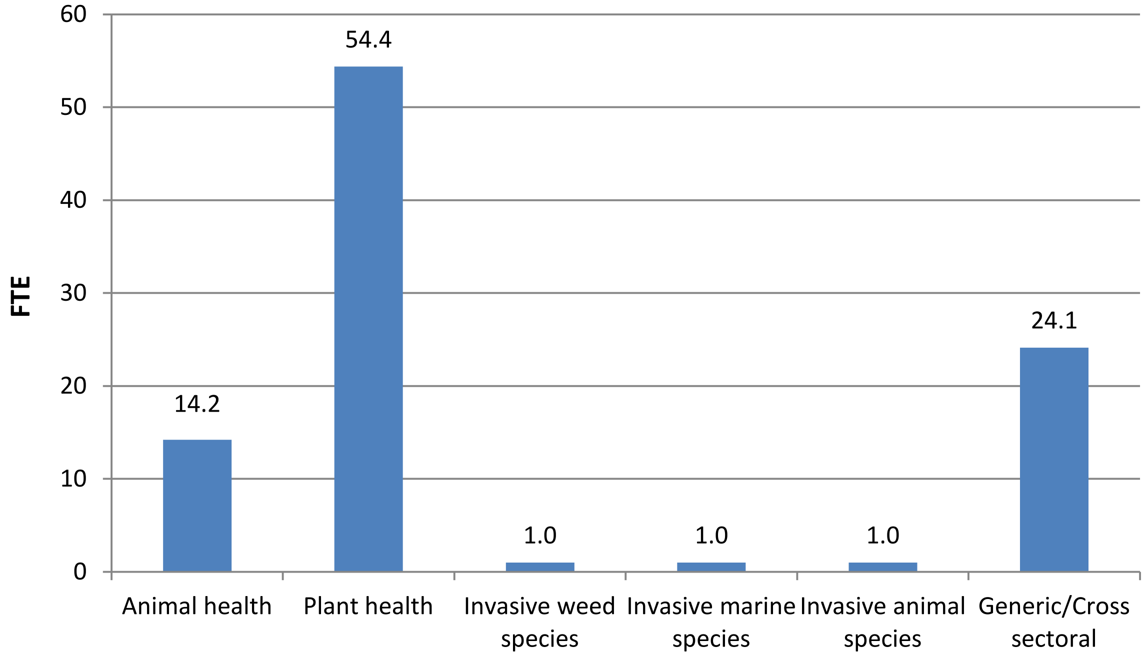

Figure 19. Full time equivalent (FTE) staff in biosecurity R&D by sector

Age

The cumulative age distribution across the biosecurity sectors shows the majority of capability was spread between the <40 (37%) and 40 - 55 (45%) years age brackets (Figure 20). The remaining capability (18%) was over 55 years of age (Figure 20).

For the animal health sector, the majority of capability (43%) was aged between 40 and 55 years of age (Figure 20). A large percentage of capability was over 55 years of age (34%) and the remaining 23% were less than 40 years of age (Figure 20).

For the plant health sector, the majority of capability was spread between the <40 (41%) and 40 - 55 (43%) years age brackets (Figure 20). The remaining 16% were over 55 years of age (Figure 20).

For the invasive weed species sector, all the capability (1 FTE) was between 40 and 55 years of age (Figure 20).

The majority of capability in the generic/cross sectoral group was spread between the <40 (42%) and 40 – 55 years age groups (38%). The remaining 20% were over 55 years of age (Figure 20).

Data was not provided for the invasive marine species or invasive animal species sectors.

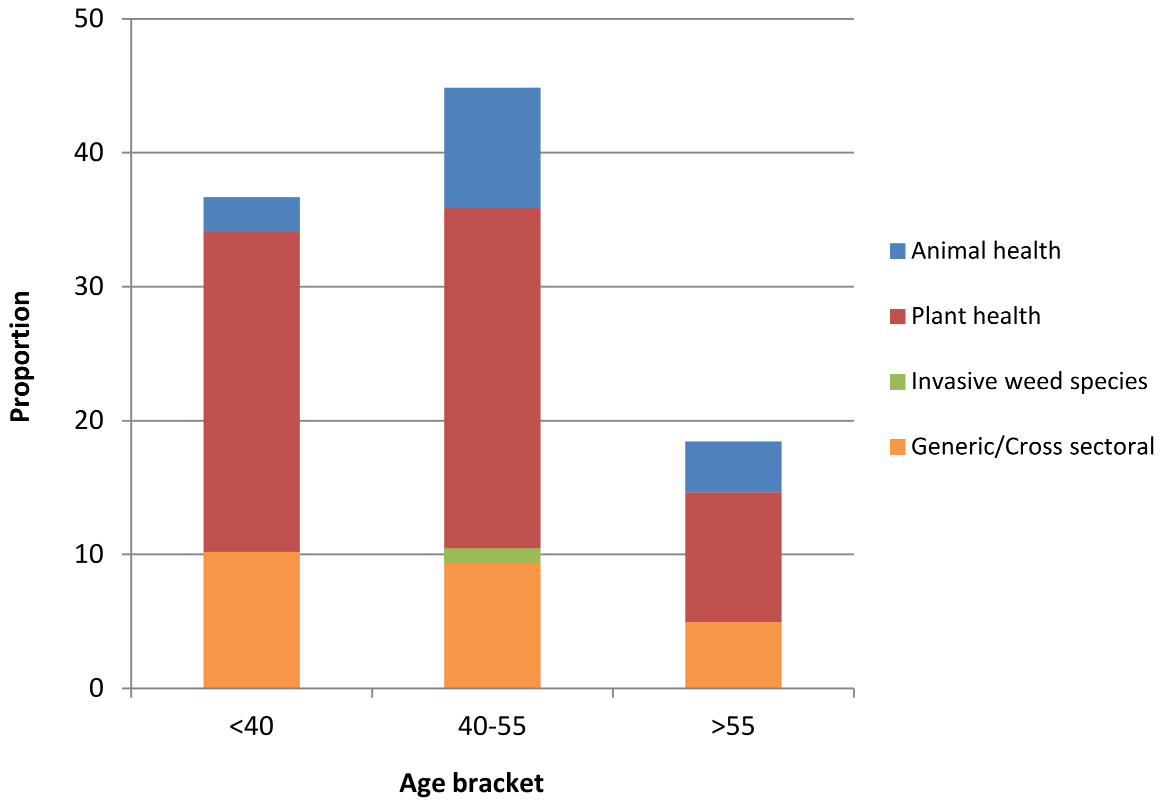

Figure 20. Proportion of Full time equivalent (FTE) staff in biosecurity R&D by age bracket by sector

Note: Results given as a proportion (% of total FTEs reported) to account for non-responses.

Research role

The predominant research role was technician, accounting for three quarters of research effort, with the remaining effort provided predominantly by researchers (Figure 21). However it should be noted that DAFF does not undertake 'bench R&D' and therefore the terms researcher and technician in this case do not refer to laboratory-based researchers and technicians. Rather, the terms researchers and technicians refer to DAFF plant and animal scientists, who undertake risk assessments and develop policies on animal, plant and public health. They research and analyse existing and new science to reach conclusions, practical outcomes and develop policy.

Post-graduate researchers made up only 0.6% of FTEs, and these postgraduates were only in the plant health sector (Figure 21). Furthermore there were no postdoctoral researchers in any of the sectors, suggesting there is little capacity to fill researcher roles into the future.

The trend differed between the individual sectors. For animal health and invasive weed species, 100% of capability was provided by technicians (Figure 21). For plant health, 96% of the capability was provided by technicians, 3% by researchers and 1% by postgraduates (Figure 21). An opposite trend was observed for generic/cross sectoral R&D in which 90% of capability was provided by researchers and the remaining 10% by technicians (Figure 21). Data was not provided for invasive marine species or invasive animal species.

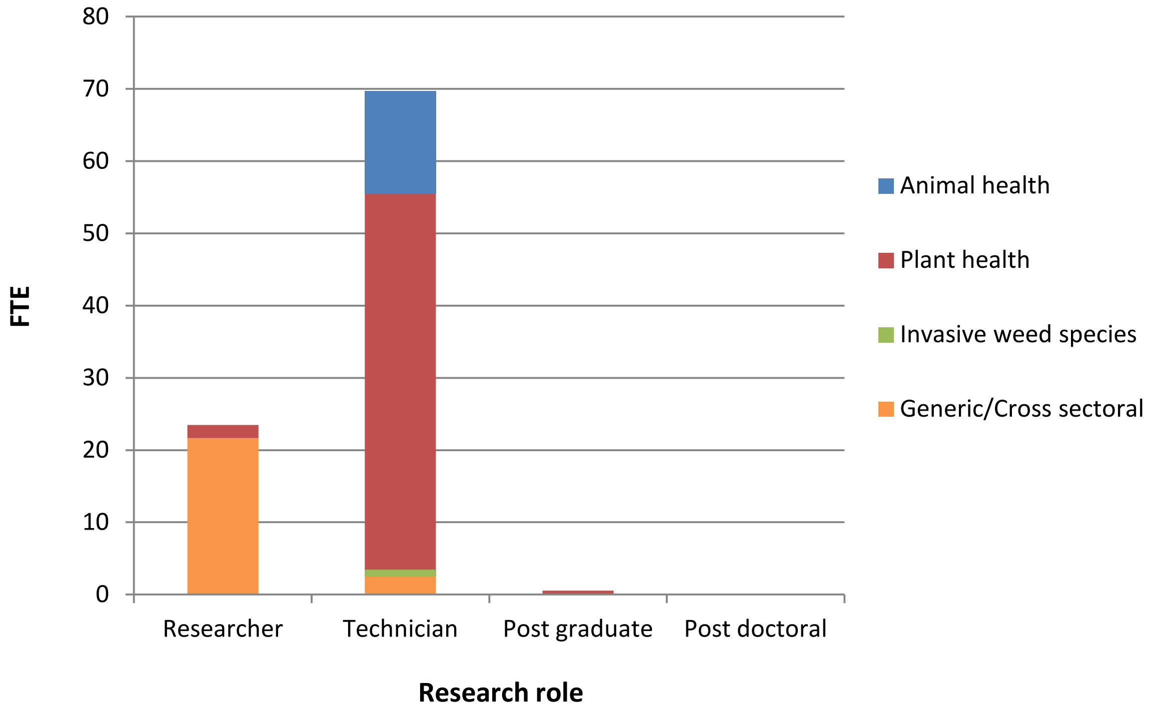

Figure 21. Full time equivalent (FTE) staff in biosecurity R&D by research role by sector

Capability against priority area

The national biosecurity R&D priority areas and objectives are defined in Appendix C.

FTEs were collected against the national biosecurity priority areas (Figure 22). The data shows that priority area 1 accounted for 52% of the total research effort across all the priorities. Within priority area 1, the majority of research effort was against objectives 1A (23%), 1D (30%) and 1E (31%). Plant health, animal health, invasive weed species and generic sectors all conducted R&D against priority area 1 (Figure 22). Data was not provided for invasive marine species or invasive animal species.

Priority area 2 accounted for 22% the total research effort across all the priorities (Figure 22). Within this priority area, research effort was fairly evenly spread between the objectives, with 25% of effort against objective 2A, 21% against objective 2B, 30% against 2C and 24% against 2D. Plant health, animal health and generic sectors all conducted R&D against this priority area (Figure 22).

Priority area 3 accounted for 24% the total research effort across all the priorities (Figure 22). Within this priority area, 91% of research effort was against objective 3A (Figure 22). Plant health, animal health and generic sectors all conducted R&D against objective 3A (Figure 22). However, only the plant health sector and generic sectors conducted R&D against objective 3B (Figure 22).

Priority area 4 accounted for only 2% of total research effort. Plant health, animal health and generic sectors all conducted R&D against this priority area (Figure 22).

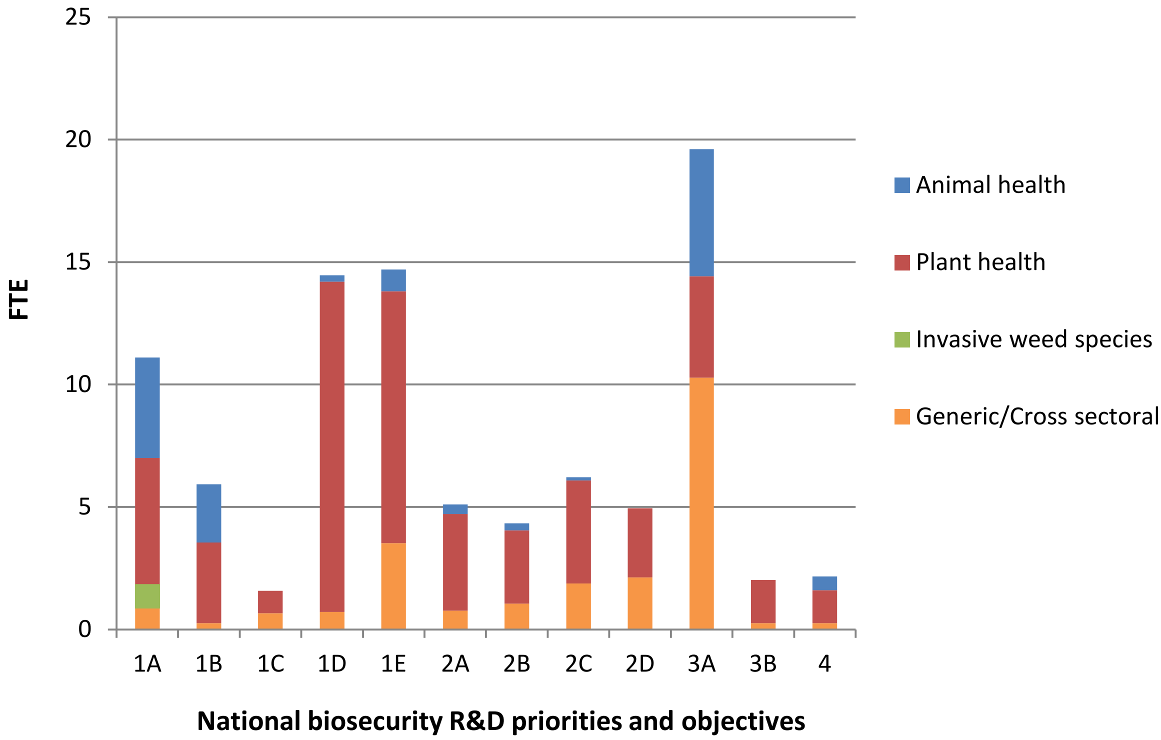

Figure 22. Full time equivalent (FTE) staff in biosecurity R&D by priority/objective by sector

Discipline

FTEs were collected against disciplines. For the animal health sector, most animal biosecurity R&D was performed by staff with veterinary science (89%) and general science (11%) expertise (Table 16). The majority (68%) of biosecurity R&D capability in the plant health sector was provided by those working in the discipline of risk analysis (Table 16). All the capability in the invasive weed species sector was in the discipline of weed ecology (Table 16). For generic/cross-sectoral R&D, the greatest capability was in the disciplines of economics (32%) and risk analysis (22%). Data was not provided for invasive marine species or invasive animal species.

Table 16. Full time staff in biosecurity R&D by discipline

Biosecurity sector	Discipline	FTEs
Animal health	Microbiologist	0.1
	Risk Analysis	0.01
	Science	1.5
	Veterinarian	12.6
Plant health	Capacity building	1.1
	Diagnostics	0.8
	Ecology	1.0
	Emergency response	0.7
	Entomology	3.6
	GIS	0.8
	Information management	1.4
	International plant protection	0.1
	Pathology	4.0
	Pest control technology	1.0
	Policy	1.7
	Quarantine	0.1
	Risk analysis	37.0
	Spatial ecology	0.2
	Surveillance	0.9
Invasive weed species	Weed ecology	1.0
Generic/Cross sectoral	Biometrics	0.8
	Ecology	3.3
	Economics	7.8
	Forest pathology	0.1
	GIS	0.3
	IT and information management	2.8
	Modelling	1.9
	Risk Analysis	5.4
	Social sciences	2.0
Invasive marine species		1.0
Invasive animal species		1.0
Total		**95.7**

4.1.2. Investment

Capability investment through wages

DAFF spends approximately $8,520,720 per annum on wages for biosecurity R&D capability across the various sectors. Approximately 54% of this amount is invested in wages for the plant health sector, 20% for the animal health sector, 1% for invasive weed species and 25% for generic/cross sectoral R&D (Figure 23). Data was not provided for invasive marine species or invasive animal species.

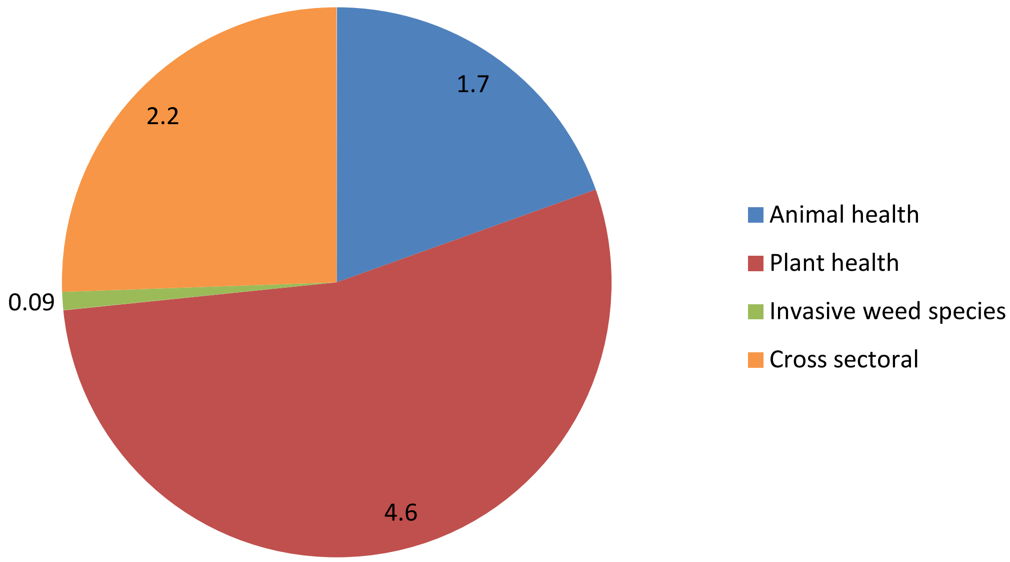

Figure 23. Investment in biosecurity R&D capability through wages (x $1,000,000)

External funding

External funding data was only provided by the Biosecurity Information Network (BIN). This generic/cross-sectoral funding amounted to $430,000 and was sourced from all state and territory governments.

4.1.3. Infrastructure

Infrastructure investments for the last 5 years (2007 – 2011) for BIN included the BioSIRT software application valued at $1,150,860. Investments forecast for the next 5 years (2012 – 2016) included a Resource Management Package valued at $150,000.

The Operational Science Program (OSP) has not made any infrastructure investments specifically for R&D infrastructure or equipment. All infrastructure and other capital expenditure made during the past 5 years has only been made to improve diagnostic services, although equipment purchased for daily technical routine work is at times being used for R&D. There are no investments forecast for the next 5 years. Key national biosecurity R&D infrastructure identified by OSP includes the Australian National Insect

Collection in Canberra, the Australian Museum in Sydney and the Australian National Herbarium - Centre for Australian National Biodiversity Research in Canberra.

4.1.4. Qualitative survey

DAFF's major outputs in biosecurity R&D are:

- Various risk assessments (animal diseases, plant pests and diseases and weeds)
- Benefit: cost analysis (BCA) for various incursion response actions (including red imported fire ant, siam weed, chestnut blight, black striped mussel)

DAFF has a national role in the following aspects of biosecurity R&D:

- Risk assessment
- BCA for pest incursion

DAFF participates in the following major international partnerships relevant to biosecurity R&D:

- Multi-lateral arrangements with QUAD countries - United States of America (United States Department of Agriculture), New Zealand (Ministry for Primary Industries), Canada (Canadian Food Inspection Agency)
- International Plant Protection Commission (IPPC) and associated activities and working groups
- World Organisation for Animal Health (OIE) and associated activities and working groups

DAFF's areas of excellence in biosecurity R&D are:

- Risk assessment
- Economic analysis
- Quantitative analysis
- Social science
- Spatial analysis
- Epidemiology (animal health)

4.2. Commonwealth Scientific and Industrial Research Organisation

4.2.1. Human Capability

Animal health data was provided by AAHL and plant health data was provided by CSIRO Ecosystem Sciences (CES) and Plant Industry. Data for invasive weed species, invasive animal species and generic/cross-sectoral R&D was provided by CES.

CSIRO employs a total of 249.9 FTEs in biosecurity research and development (R&D) across the biosecurity sectors. All sectors except invasive marine species were represented. Animal health had the largest capability (64%) of the sectors (Figure 24).

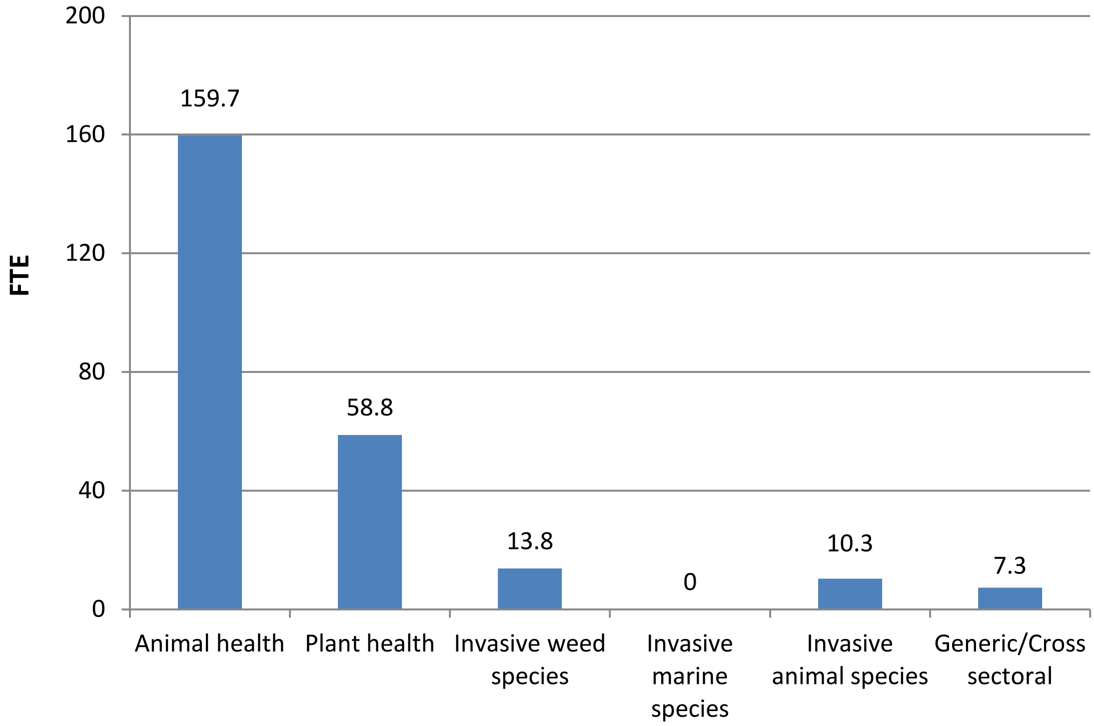

Figure 24. Full time equivalent (FTE) staff in biosecurity R&D by sector

Age

The cumulative age distribution across the biosecurity sectors shows the majority of capability was spread between the <40 (44%) and 40 - 55 (42%) years age brackets (Figure 25). The remaining capability (14%) lied in the >55 age group (Figure 25).

This trend was similar for the animal health sector, with the majority of capability spread between the <40 (44%) and 40 – 55 (41%) years age group, and the remaining 15% of capability over 55 years of age (Figure 25).

For the plant health sector, the greatest capability was in the 40 - 55 years age bracket (49%; Figure 25). A large percentage of capability was less than 40 years of age (38%) and the remaining 15% were over 55 (Figure 25).

For the invasive weed species sector, the majority of capability was less than 40 years of age (48%). A large percentage were between the ages of 40 and 55 (34%) and the remaining 18% were over 55 years of age (Figure 25).

For invasive animal species, 66% of capability was less than 40 years of age, 24% was between 40 and 55 years of age and only 10% were over 55 (Figure 25).

The majority of capability in the generic/cross sectoral group was spread evenly between the <40 and 40 – 55 years age groups (43% each), and the remaining 14% of capability was over 55 years of age (Figure 25).

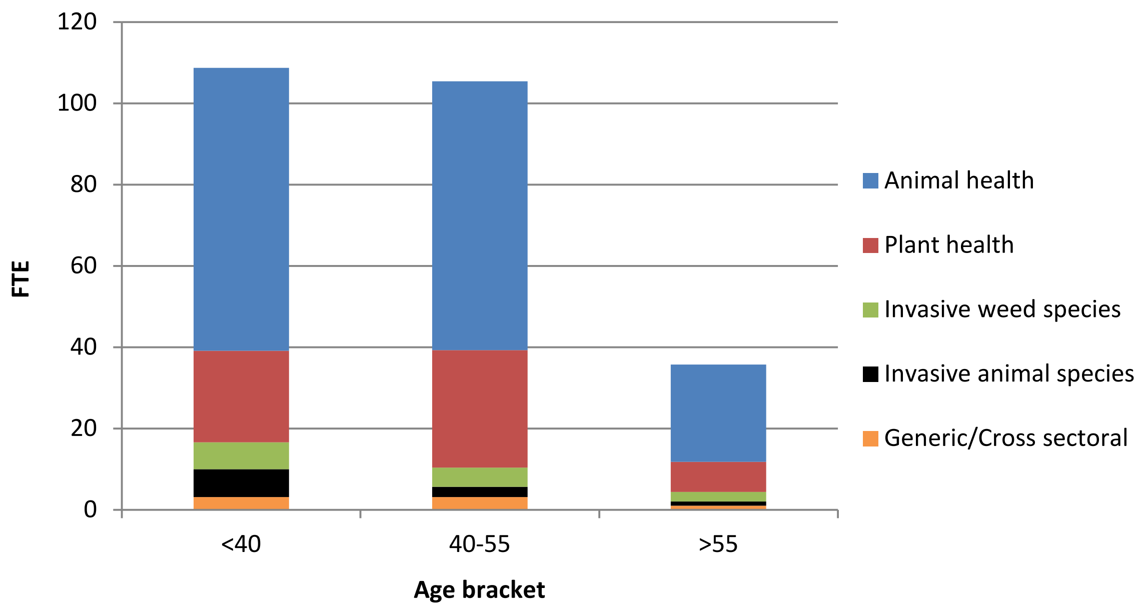

Figure 25. Full time equivalent (FTE) staff in biosecurity R&D by age bracket by sector

Research role

The predominant role in biosecurity R&D in CSIRO was technician, accounting for 48% of research effort (Figure 26). The majority of remaining effort (34%) was provided by researchers. Only 8% of capability was provided by postgraduates, and 11% by postdoctoral researchers (Figure 26).

The animal health sector showed a similar trend, with the majority of capability provided by technical support (52%) and only 29% by researchers (Figure 26). The remaining capability was provided by postgraduates (12%) and postdoctoral researchers (7%; Figure 26).

For the plant health sector, the majority of capability was also provided by technicians (46%; Figure 26). The remaining capability was provided by researchers (39%) and postdoctoral researchers (15%; Figure 26).

The invasive weed species sector had similar capability provided by researchers (43%) and technicians (45%; Figure 26). In addition 2% of capability was provided by postgraduates and 10% by postdoctoral researchers (Figure 26).

Invasive animal species showed a different trend, with the majority of capability provided by postdoctoral researchers (50%). The remaining capability was provided by researchers (34%), technicians (15%) and postgraduates (1%; Figure 26).

For generic/cross-sectoral R&D, the majority of capability was provided by researchers (67%) and the remaining was provided by technical support (24%) and postdoctoral researchers (10%; Figure 26).

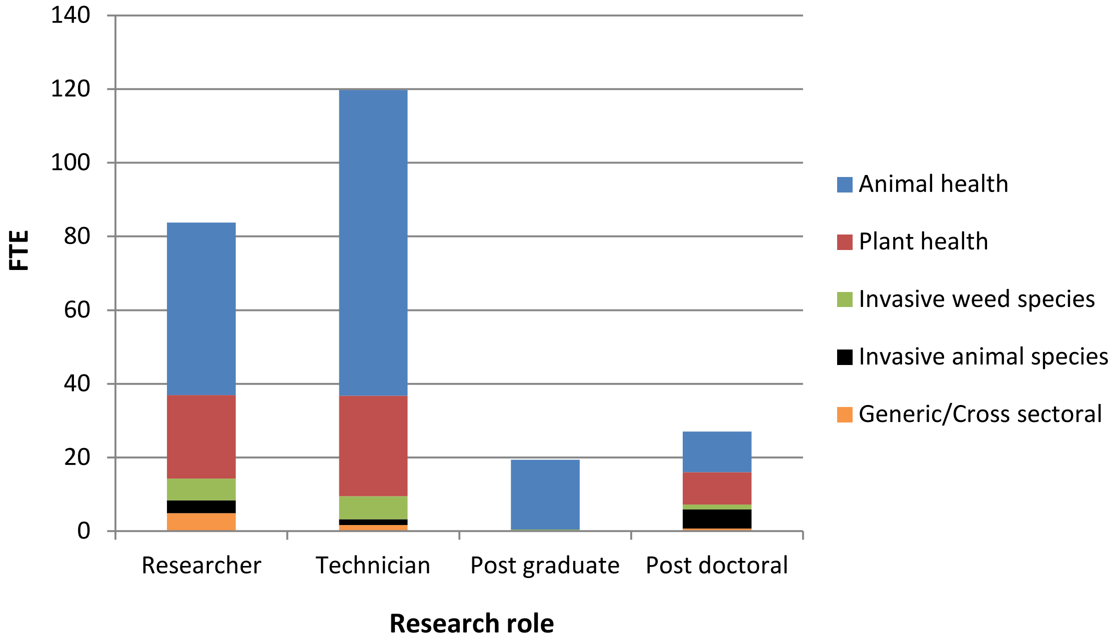

Figure 26. Full time equivalent (FTE) staff in biosecurity R&D by research role by sector

Capability against priority area

FTEs were collected against the national biosecurity priority areas. Data for plant health, invasive weed species and invasive animal species was provided together (Figure 27). The data shows the majority of research effort was against objectives 1A (12%), 1B (25%), 1D (14%), 1E (11%), 2B (12%) and 2D (10%; Figure 27). All priority areas and objectives had some R&D conducted against them (Figure 27).

Priority area 1 accounted for 65% the total research effort across all the priorities (Figure 27). Within this priority area, the majority of research effort (39%) was against objective 1B, and all sectors except generic/cross sectoral conducted R&D against this objective (Figure 27).

Priority area 2 accounted for 29% the total research effort across all the priorities (Figure 27). Within this priority area, the greatest research effort was against objective 2B (40%), and all sectors except generic/cross sectoral conducted R&D against this objective (Figure 27).

Approximately 5% of the total research effort was against priority area 3 (Figure 27). The majority of effort within this priority area was against objective 3A (65%), and all sectors except animal health conducted R&D against this objective (Figure 27).

Only 2% of the total research effort was against priority area 4 and all sectors except animal health and generic/cross sectoral conducted R&D against this objective (Figure 27).

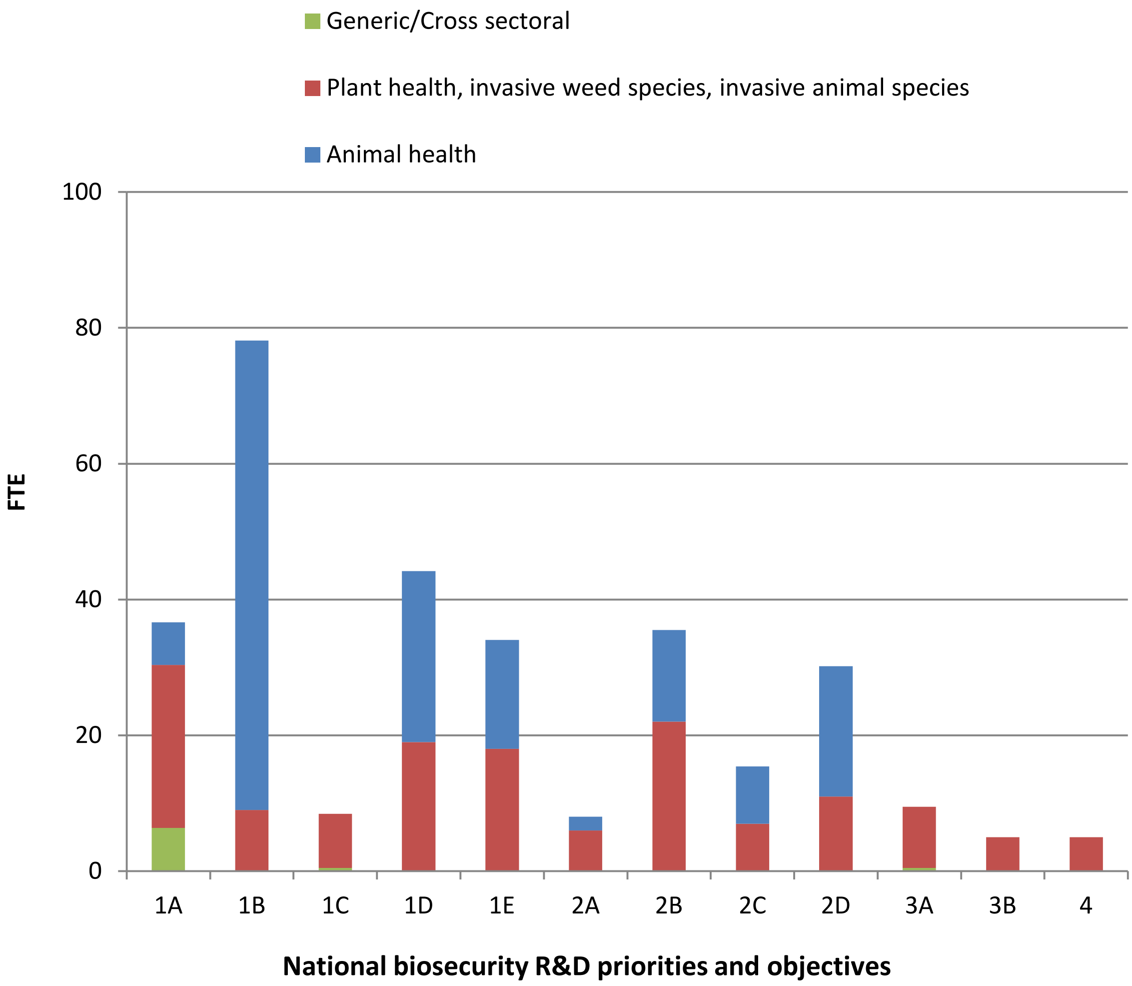

Figure 27. Full time equivalent (FTE) staff in biosecurity R&D by priority/objective by sector

Discipline

FTEs were collected against disciplines. In Table 17, FTEs are presented as the percentage of total FTEs for each sector, as disciplines were not recorded for all personnel. For animal health, 16 disciplines were represented, with the greatest percentage of FTEs in the disciplines of molecular biology (23%) and diagnostics (18%). For the plant health sector, capability was spread between 18 disciplines, with the largest percentage of FTEs in the disciplines of molecular biology (34%) and disease/pest resistance (30%). For invasive weed species, 5 disciplines were represented, with ecology containing the largest percentage of FTEs (71%). Invasive animal species only had capability reported in two disciplines, with 97% of the reported FTEs in the discipline of ecology modelling (Table 17). The generic/cross-sectoral group contained capability across 5 disciplines, with 51% of FTEs reported to be against the discipline of social and economic sciences (Table 17).

Table 17. Proportion of staff in biosecurity R&D by discipline

Biosecurity sector	Discipline	% of FTEs
Animal health	Anatomical pathology	1.9
	Animal science	3.6
	Bacteriology	0.6
	Bioinformatics	1.9
	Diagnostics	17.9
	Entomology	0.3
	Epidemiology	1.9
	Immunology	9.4
	Microbiology	0.6
	Microscopy	3.1
	Molecular biology	22.9
	Protein Chemistry	5.9
	Serology	6.7
	Tissue culture	1.3
	Veterinarian	0.6
	Virology	21.4
Plant health	Agronomy	0.2
	Bee pathology	1.2
	Bioinformatics	1.3
	Breeding	0.9
	Disease & pest resistance	29.6
	Ecology	2.2
	Evolutionary biology	4.2
	Functional genomics	1.3
	Molecular biology	33.7
	Modelling	3.8
	Nematode systematist	1.5
	Pathology	14.0
	Population ecology	0.8
	Risk analysis	3.8
	Soil microbial ecology	0.5
	Spatial ecology	0.8
	Stored grains engineer	0.3
	Systematics	0.1

Biosecurity sector	Discipline	% of FTEs
Invasive weed species	Ecology	70.7
	Molecular biology	2.1
	Modelling	11.5
	Population ecology	12.6
	Population genetics	3.1
Invasive animal species	Ecology	3.5
	Ecological modelling	96.5
Generic/Cross sectoral	Ecological modelling	9.3
	GIS specialist	13.7
	Proteomics	12.4
	Risk analysis	13.2
	Social and economic sciences	51.4
Total		**249.9**

4.2.2. Investment

Capability investment through wages

CSIRO spends approximately $22,100,352 per annum on wages for biosecurity R&D capability across the various sectors (Figure 28). Approximately 62% of this amount was invested in wages for the animal health sector, 25% for the plant health sector, 6% for invasive weed species, 4% for invasive animal species and 3% for generic/cross-sectoral R&D (Figure 28).

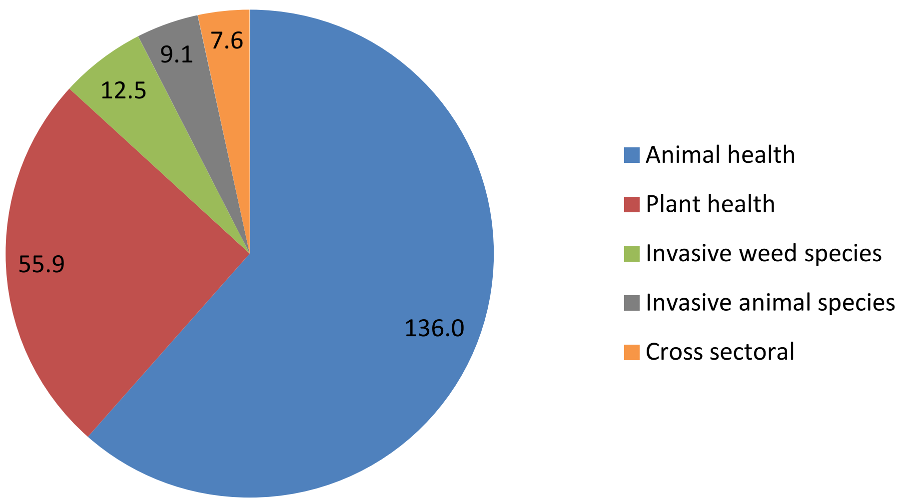

Figure 28. Investment in biosecurity R&D capability through wages (x $100,000)

External funding – amounts

External funding information was only received for the animal health and plant health sectors. Animal health funding information related to AAHL. Plant Industry funding information was for CSIRO Plant Industry only, and did not include funding information for CES.

CSIRO received external funding in 2011 amounting to $14,170,000. The majority (62%) was directed to the plant health sector.

External funding – sources

Sources of external investment (for 2011) for CSIRO are listed in Table 18. The major investors in animal health R&D included MLA, MAT and the Poultry Cooperative Research Centre (Poultry CRC). The major investors in plant health (Plant Industry only) included GRDC, GWRDC and the African Agricultural Technology Foundation.

Table 18. Sources of external investment for Biosecurity R&D in CSIRO

Biosecurity sector	Source of external investment
Animal health	**Australian Government**
	Animal biosecurity CRC
	Poultry CRC
	DAFF
	NHMRC
	Rural RDCs
	MLA
	RIRDC
	Commercial funds
	CSL Limited
	MAT
	Pfizer
	Overseas funds
	US NIH
Plant health	**Australian Government**
	DISSR
	ACIAR
	ARC
	Rural RDCs
	GRDC
	GWRDC
	RIRDC

	Overseas funds
	African Agricultural Technology Foundation
	Finkel Foundation
	Gates Foundation
	Two Blades Foundation
	US Cornell University
	US NIH
	US National Science Foundation

External funding – against priority area

External funding against national biosecurity R&D priorities and objectives is presented for animal health (AAHL) and plant health (Plant Industry only). Figure 29 shows that priorities 1, 3 and 4 were externally funded across the sectors. For priority 1, all objectives were funded except for 1C, however for priority 2, only objectives 2B and 2D were funded. The greatest investment across the sectors (62%) was against priority 2, objective 2D, while only 0.6% was against priority 4 (Figure 29).

The animal health sector received funding for all priorities except 3, and the greatest percentage of investment for the sector (34%) was against priority 1, objective 1E (Figure 29). In contrast, plant health only received external funding against objective 2D (Figure 29).

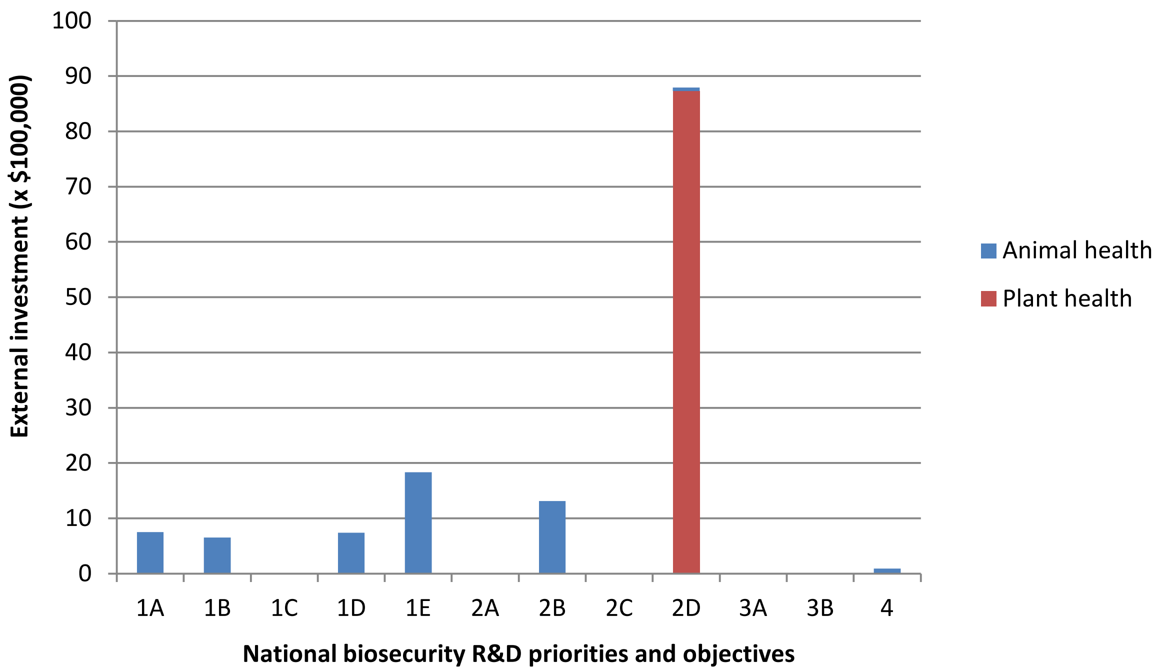

Figure 29. External investment in biosecurity R&D by priority/objective

4.2.3. Infrastructure

Infrastructure investments for AAHL in the last 5 years (2007 – 2011) included AAHL Geelong Capital upgrades valued at $32,000,000 and investment through NCRIS valued at $12,500,000. AAHL was identified as the key national biosecurity R&D infrastructure for animal health.

4.2.4. Qualitative survey

AAHL provided a response to the questionnaire for the animal health sector and Plant Industry provided a response for the plant health and invasive weed species sectors.

Animal health

Future increases in AAHL investment in animal health R&D will be in the area of new, emerging and emergency diseases of livestock, including zoonotic agents. AAHL will continue to grow the investment in this area, in line with the increasing risk.

AAHL's top 10 outputs in biosecurity R&D include:

- New diagnostic tests for livestock disease
- Improved risk understanding process
- Characterisation of causative viruses to empower molecular epidemiology
- New and innovative preventative approaches through disease resistant animals
- New generation vaccines and therapeutics
- Basic understanding of host switching
- Basic understanding of bat immunology
- Innate immunity processes of insects
- Improved biosecurity information process
- New and improved biosecurity facility and technologies

AAHL takes national and international leadership roles in all aspects of infections requiring the use of high containment facilities. This includes both the operation of such facilities in the underpinning research and in the delivery of a diagnostic service, in particular for the following:

- Develop the knowledge base for assessing and managing the risks of new diseases, invasion pathways, and the susceptibility of hosts and ecosystems to invasion
- Enhance detection, surveillance and diagnostic systems
- Develop knowledge and strategies to prevent and contain the spread of diseases within national borders
- Develop tools and decision-making frameworks for prevention and eradication
- Develop effective and integrated approaches to managing established diseases of national priority
- Understand risk factors that drive emergence of new pests and diseases
- Understand the interaction of pests and diseases with the invaded system

AAHL maintains international partnerships in biosecurity R&D with numerous research organisations, government agencies, universities and companies.

The organisation's areas of excellence include understanding of pathogens of livestock that are new, emerging or exotic, research into exotic pathogens, the delivery of a diagnostic service for new, emerging and exotic pathogens of livestock, including zoonotic agents and a broad range of multi-discipline research capabilities including:

- Virology
- Immunology
- Imaging and microscopy
- Pathogenesis
- Large scale animal facilities at PC2 and BCL-3 and -4
- Development of vaccines and therapeutics
- Molecular diagnostics

Plant health

CSIRO Plant Industry plans to maintain the current level of funding to all existing areas of bio-security related research.

The organisation's top ten outputs in biosecurity R&D include:

- Delivering molecular markers to the wheat breeding industry: Plant Industry has had a major focus on DNA marker development for rust resistance genes in wheat.
- Necrotrophic fungal pathogens – Plant Industry's research in this area is aimed at (a) improving disease management b) identifying and exploiting weaknesses in the pathogen (c) developing novel resistance sources and (d) improving host plant resistance through pre-breeding.
- Lupin pest resistance – Plant Industry's research aimed at understanding plant defence against sap-sucking insect pests using powerful genetic and genomic approaches, the provision of Bt-legumes with built-in protection against caterpillar pests and research addressing the impact of root-infecting pathogens.
- Grape powdery and downy mildew resistance – Plant Industry's molecule genetics approach for conferring resistance to powdery mildew and downy mildew in commercial grape varieties.
- Cereal virus resistance - Barley yellow dwarf virus (BYDV) and Cereal yellow dwarf virus (CYDV) resistance markers delivered by Plant Industry and deployed in new varieties of cereals in Australia and China
- Insect resistance – Plant Industry research underpinning the development of *Bacillus thuringiensis* (BT) cotton varieties and the development of BT varieties of legumes and chickpeas as part of foreign aid projects in Africa.
- Weed Control - a number of important outcomes from Plant Industry over the past five years in areas of population genetics, risk assessment and weed control.

CSIRO Plant Industry provides a national/international leadership role in molecular plant-microbe genomics, interactions & evolution, molecular genetics of cereal rust diseases and resistance – recognised in the Grains industry R, D & E plan, and Grape powdery and downy mildew resistance.

CSIRO Plant Industry maintains international partnerships in biosecurity R&D with the following organisations:

- European Union FP6 project Grain Legumes Integrated Project

- The Noble Foundation, USA
- University of California, Davis
- The John Innes Centre, UK
- International Maize and Wheat Improvement Centre (CIMMYT), Mexico
- Rothamsted Research Centre, UK
- Jiangsu Academy of Agricultural Sciences, China
- University of Zurich, Switzerland
- University of Minnesota, USA
- US Department of Agriculture
- Broad Institute, Massachusetts Institute of Technology, USA
- French National Institute of Agriculture (INRA)
- Two Blades Foundation, USA
- Bill and Melinda Gates Foundation
- Borlaug Global Rust Initiative
- Chinese Academy of Science
- Ahmadu Bello University, Nigeria
- Assam Agricultural University, Jorhat, India
- Purdue University, USA
- Agriculture and Agri-food Canada - Cereal Research Centre, Winnipeg, Canada
- Colorado State University, USA

CSIRO Plant Industry’s areas of excellence include plant – pathogen interactions (both biotrophic and necrotrophic).

4.3. Victorian Government: Department of Primary Industries

4.3.1. Human capability

DPI Vic employs a total of 103.9 FTEs in biosecurity R&D across the biosecurity sectors (Figure 30). All sectors except invasive animal species were represented. The plant health sector accounted for almost 60% of the capability and animal health accounted for 25%. Remaining capability was spread between invasive weed species (13%), invasive marine species (1%) and generic/cross-sectoral R&D (2%).

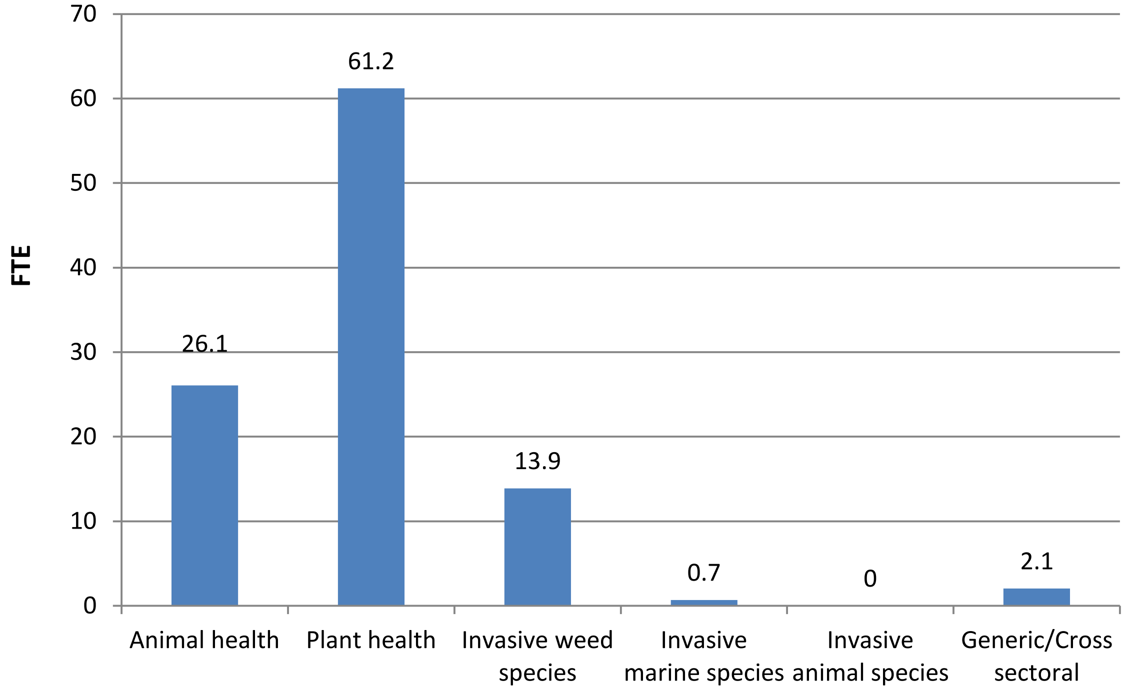

Figure 30. Full time equivalent (FTE) staff in biosecurity R&D by sector

Age

The cumulative age distribution across the biosecurity sectors shows that almost half the capability was between 40 and 55 years of age (Figure 31). The remainder of the capability was fairly evenly spread between the <40 and >55 age groups.

The trend was similar for the animal health, plant health and invasive weed species sectors in which approximately half the capability was in the 40 – 55 age bracket (Figure 31). For plant health the remainder of the capability was evenly spread between those less than 40 and those over 55 years of age (Figure 31). However for animal health there were twice as many staff aged less than 40 than over 55 years of age, showing a greater capacity to retain researchers into the future compared to plant health (Figure 31). In contrast, for invasive weed species there was similar capability in the 40 -55 and >55 age groups and almost 2 fold less capability in the <40 age bracket showing a reduced capacity for future capability (Figure 31). A different trend was observed in the invasive marine species sector in which there was 4-fold greater capability less than 40 compared to those between 40 and 55 and there were no researchers over 55 (Figure 31).

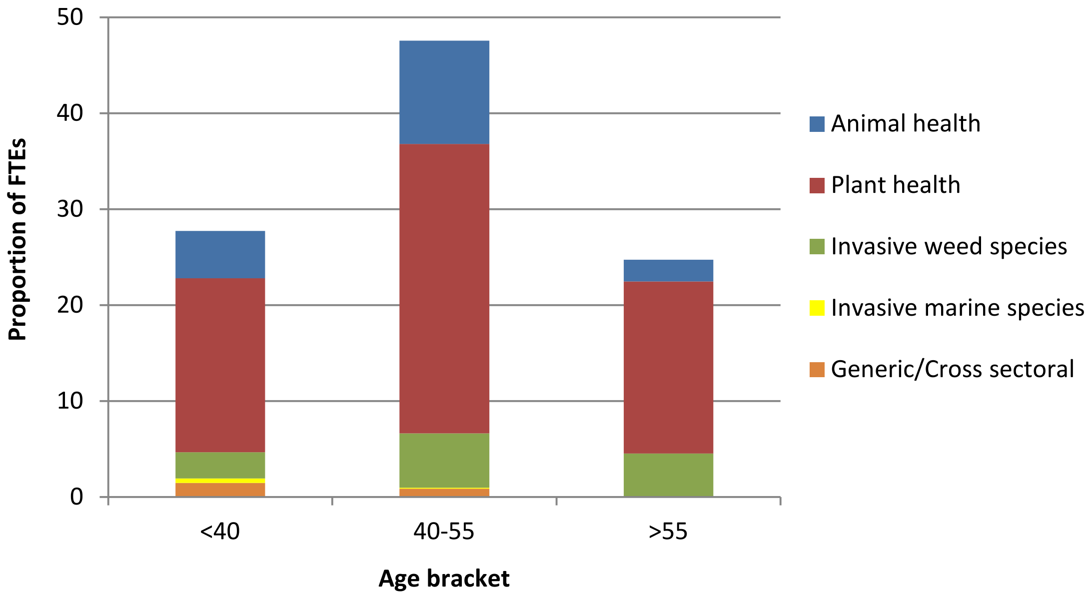

Figure 31. Proportion of Full time equivalent (FTE) staff in biosecurity R&D by age bracket by sector

Note: Results given as a proportion (% of total FTEs reported) to account for non-responses.

Research role

Not surprisingly, the predominant research role was researcher, accounting for almost three quarters of research effort, with the remaining effort provided predominantly by technical support (Figure 32). Postgraduate researchers provided only 1.7% of FTEs, and these postgraduates were only in the animal health and generic/cross-sectoral sectors (Figure 32). Furthermore there were no postdoctoral researchers suggesting there is little capacity to fill researcher roles into the future for all sectors (Figure 32).

An interesting difference noted between sectors was that animal health had a lower ratio of researchers to technicians (1.5) compared to plant health (4), and invasive weed species (3). An opposite trend was observed for invasive marine species in which there was greater technical than researcher capability (2.5 fold more) although this was likely to be a reflection of the low overall FTEs in this sector (Figure 32).

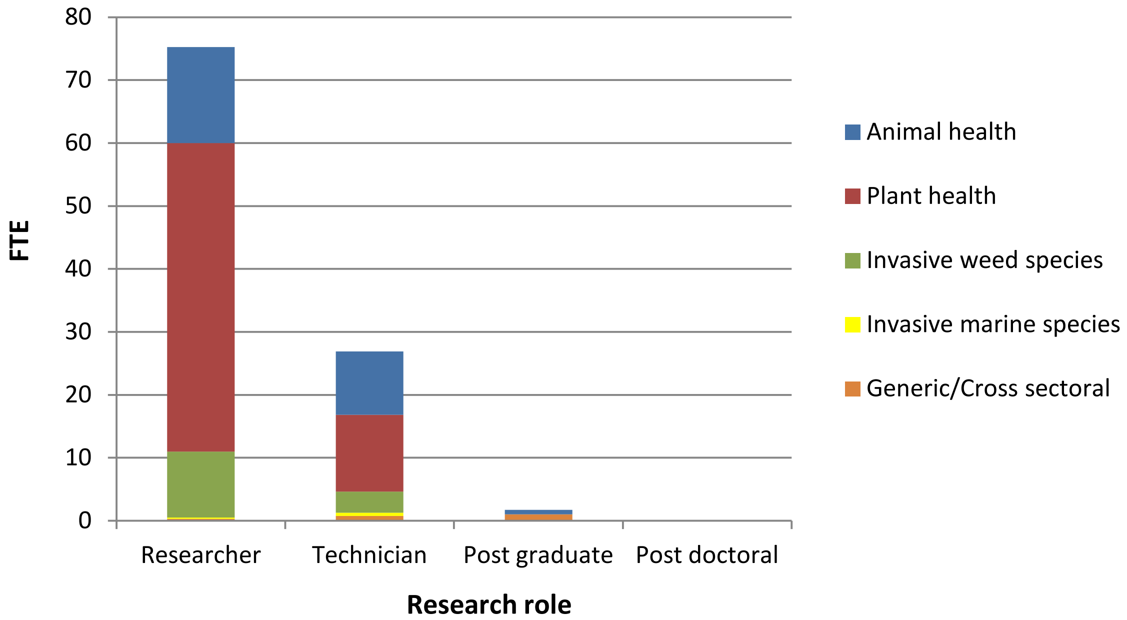

Figure 32. Full time equivalent (FTE) staff in biosecurity R&D by research role by sector

National biosecurity R&D priority areas

The national biosecurity R&D priority areas and objectives are defined in Appendix C.

FTEs were collected against the national biosecurity priority areas. The data shows that DPI Vic spends over 96% of effort on priorities 1 and 2 with over 80% of that effort invested in objectives 1B and 2B (Figure 33).

Priority area 1 accounted for 49% the total research effort across all the priorities (Figure 33). Within this priority area, the majority of research effort (98%) was against objectives 1A and 1B (Figure 33). However plant health was the only sector working against objective 1A, and plant health and animal health were the only sectors working against 1B. A very low amount of research effort (<2%) was spent against the remaining priority 1 objectives (1C – E; Figure 33).

Priority area 2 accounted for 47% the total research effort across all the priorities (Figure 33). Within this priority area, the majority of research effort (86%) was against objective 2B and the sectors conducting this R&D were plant health and invasive weed species (Figure 33). Animal health, plant health, invasive marine species and generic sectors all conducted research against objective 2A which accounted for 9% the research effort against priority 2. However only the animal and plant health sectors conducted R&D against objective 2C and only plant health conducted R&D against objective 2D (Figure 33). Together objectives 2C and D accounted for only 5% the research effort against this priority area (Figure 33).

Only the plant health and generic sectors conducted R&D against priority area 3 which accounted for less than 1% the total research effort across all the priorities (Figure 33). Similarly for priority area 4, only plant health and the generic sector conducted research against this priority and the total research effort against this priority area was low (2%; Figure 33).

Looking at the sectors individually, animal health conducted biosecurity R&D across priority areas 1 and 2 only, with the majority of R&D occurring against objective 1B (92%; Figure 33).

Plant health conducted R&D against all the priorities and objectives except for 1D, 1E and 3A (Figure 33). The majority of R&D was against objective 2B (47%). For invasive weed species, all the R&D was conducted against priority area 2, objective 2B (Figure 33). Invasive marine species conducted R&D against priorities 1 and 2, however only against objectives 1B and 2A (Figure 33). Of these objectives, the majority of time (86%) was spent against objective 1B. The generic/cross-sectoral R&D was conducted against all the priority areas, however only against the objectives 1E, 2A and 3A (Figure 33). The majority of research effort was against objective 3A (33%) and priority 4 (36%).

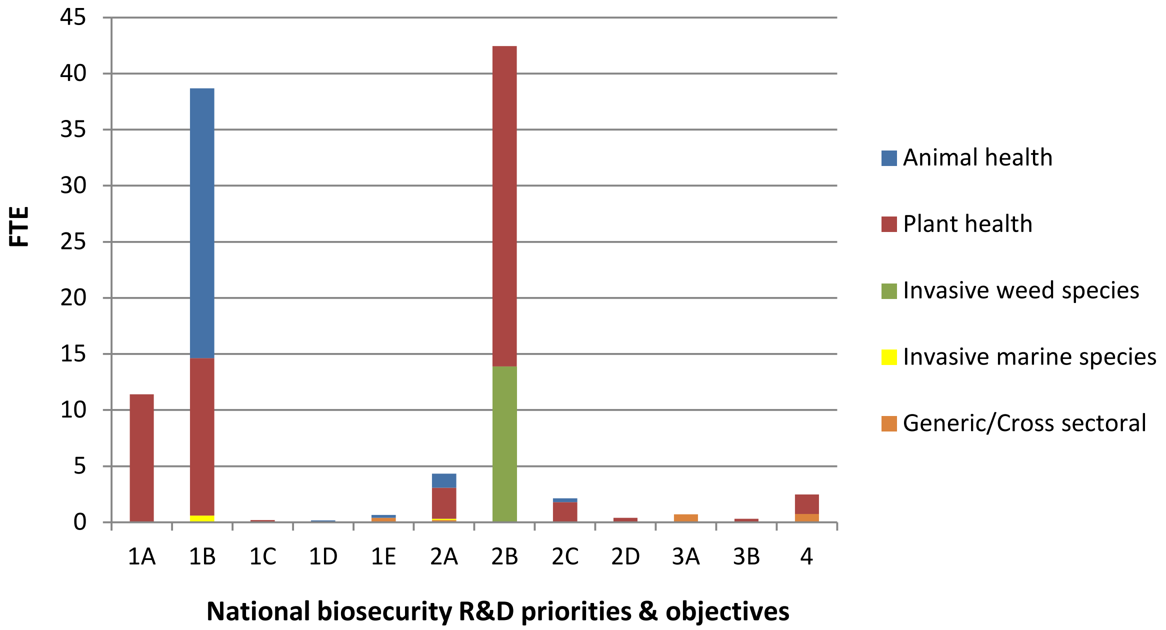

Figure 33. Full time equivalent (FTE) staff in biosecurity R&D by priority/objective by sector

Discipline

FTEs were collected against disciplines (Table 19). For the animal health sector, microbiology had the largest capability (36%) and entomology the lowest capability (4%; Table 19). For plant health, the discipline with the greatest capability was mycology (48%) and the lowest capability was horticulturist (0.3%; Table 19). The invasive weeds sector had capability across four disciplines only, with the greatest capability in ecology (46%) and the lowest in pathology (7%; Table 19). Capability in invasive marine species was across two disciplines only, with 71% of this capability in surveillance and the remaining 29% in GIS (Table 19). For the generic/cross-sectoral group, capability was in the disciplines of economics (38%), risk analysis (24%) and IT and information management (38%; Table 19).

Table 19. Full time equivalent (FTE) staff in biosecurity R&D by discipline

Biosecurity sector	Discipline	FTEs
Animal health	Anatomical pathologist	4
	Bacteriology	4
	Entomology	1
	Epidemiology	1.3
	Microbiology	9.4
	Pathobiology	2
	Virology	4.4
Plant health	Bacteriology	2
	Diagnostics	3
	Entomology	13.1
	Horticulturist	0.2
	Microbiology	3
	Molecular biology	1.6
	Mycology	27.4
	Nematology	2.3
	Taxonomy	1.3
	Virology	7.2
Invasive weed species	Biological control	4
	Ecology	6.4
	Pathology	1
	Risk analysis	2.5
Invasive marine species	GIS	0.2
	Surveillance	0.5
Generic/Cross sectoral	Economics (in biosecurity)	0.8
	IT and information management	0.8
	Risk analysis	0.5
Total		**103.9**

4.3.2. Investment

Capability investment through wages

DPI Vic spends approximately $7,277,796 per annum on wages for biosecurity R&D capability across the various sectors (Figure 34). Approximately 60% of this amount was invested in wages for the plant health sector, 23% for the animal health sector, 14% for invasive weed species, 1% for invasive marine species and 2% for generic/cross-sectoral R&D (Figure 34).

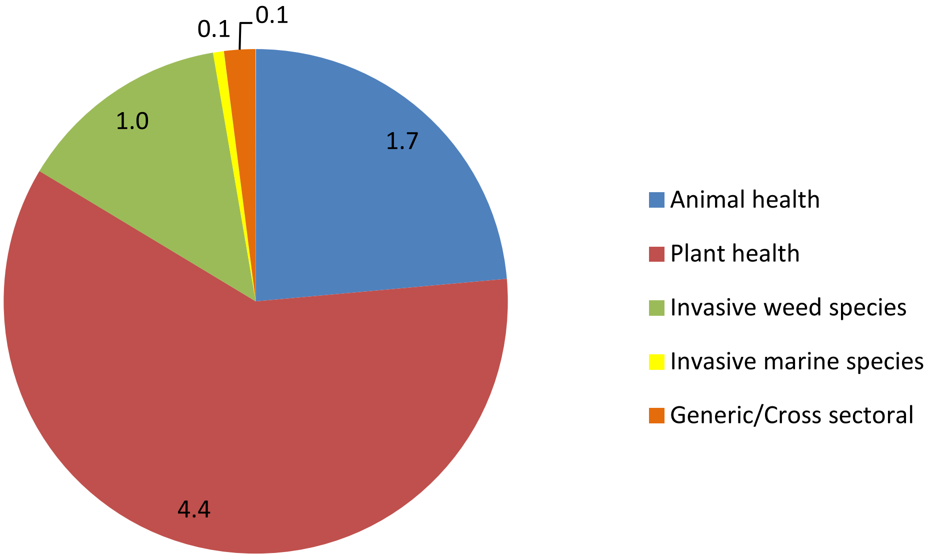

Figure 34. Investment in biosecurity R&D capability through wages (x $1,000,000)

External funding – amounts

The department received external funding in 2011 amounting to approximately $5,617,603. Plant health received the greatest amount of external funding, representing almost 70% the total amount invested across the sectors (Figure 35). Despite having lower capability, invasive weed species received more external funding than animal health (21% compared to 8% respectively). Invasive marine species received 1.5% the total amount externally invested across the sectors and generic/cross-sectoral R&D received no external funding.

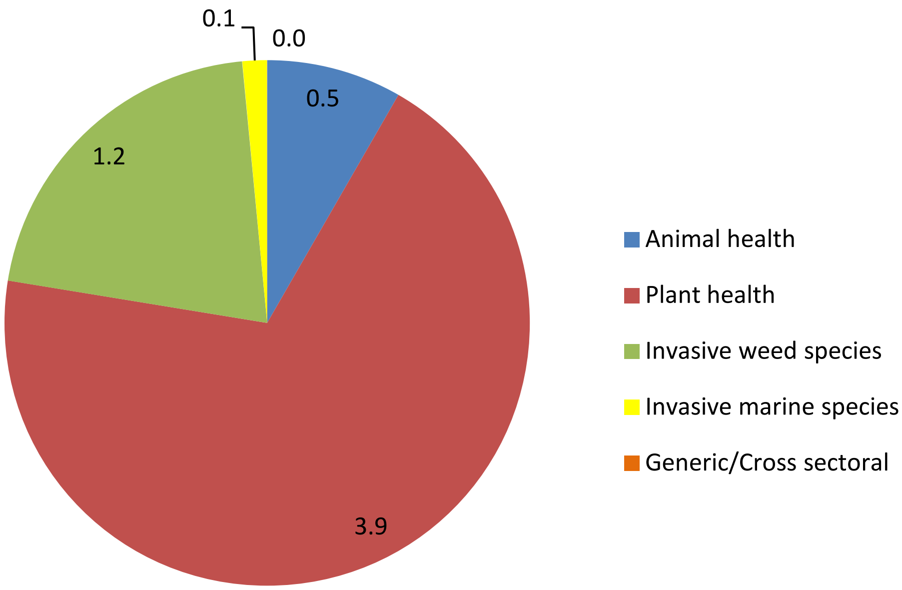

Figure 35. External investment in biosecurity R&D by sector (x $1,000,000)

External funding – sources

Sources of external investment (for 2011) for DPI Vic were varied (Table 20). One of the major investors for animal health was the Victorian Department of Human Services, and for plant health the major investors included HAL, GRDC and GWRDC. For invasive weed species, the RIRDC was a major investor and for invasive marine species, the Victorian Department of Sustainability and Environment was the only external funder.

Table 20. Sources of external investment for Biosecurity R&D in DPI Vic

Biosecurity sector	Source of external investment
Animal health	**State government**
	DAFF Queensland
	Department of Human Services, Victoria
	Rural RDCs
	FRDC
Plant health	**Australian Government**
	CRCNPB
	DAFF
	Rural RDCs
	GRDC
	HAL
	GWRDC
	Miscellaneous
	Australian Pacific Network (APN)
	Other Industry sources
	Phylloxera Board South Australia
Invasive weed species	**State government**
	Department Sustainability and Environment, Victoria
	Rural RDCs
	RIRDC
	Miscellaneous
	Irrigation Company
Invasive marine species	**State government**
	Department Sustainability and Environment, Victoria

External funding – against priority area

External funding by national biosecurity R&D priorities and objectives shows that the major investment across the priorities (83%) was against objective 2B (Figure 36). However, only plant health and invasive weed species received funding for this objective (Figure 36). Objective 1B had the second highest level of external investment across the priorities (14%)

and animal health, plant health and invasive marine species all conducted R&D against this objective (Figure 36).

There was a small amount of external investment in objectives 1A (0.4%) and 1E (0.2%) and only the plant health sector received funding for these objectives (Figure 36). Animal health was the only sector to receive funding against objective 2A, and this was a small amount (0.7%) of the total investment across the priorities and sectors (Figure 36). The only other objective which received external funding was 2C and this amounted to only 1% the total investment across the priorities and only went towards the plant health sector (Figure 36).

There was no external funding for any of the sectors against priorities 3 and 4 (Figure 36).

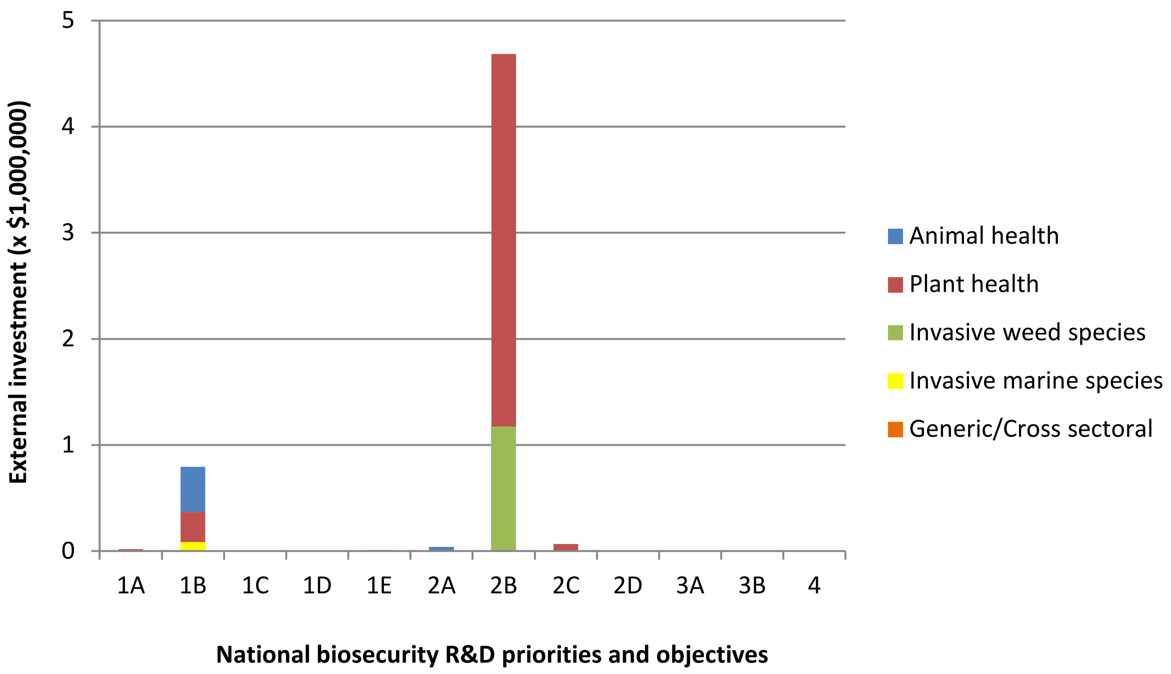

Figure 36. External investment in biosecurity R&D by priority/objective by sector

4.3.3. Infrastructure

DPI Vic identified over $290,000,000 worth of infrastructure investments over the last 5 years (2007-2011). These included a number of priceless items including the maintenance of taxonomic collections.

The primary investment was in the Centre for AgriBioscience[26] (AgriBio), located at La Trobe University's Bundoora campus. AgriBio is a 20,000m^2 building with 3,000m^2 of glasshouses as surge capacity for biosecurity. The buildings include facilities dedicated to biosecurity including QC2 and QC3 animal laboratories including post-mortem and histology suite, QC2 and QC3 plant laboratories and QC2 and QC3 glasshouses. Also included is an animal tissue digester with 500kg capacity that is unique to Australia ($1,000,000), a backup post-mortem incinerator and an Actini PC3 4,000L liquid waste, continuous flow, treatment plant, one of

[26] Note that this infrastructure was a joint venture between the Victorian Government and La Trobe University

seven in Australia that is AQIS certified ($1,000,000). As well as this, DPI Vic manages a dedicated AQIS accredited glasshouse and post-entry quarantine facility at Horsham with a recent QC2 laboratory upgrade valued at $50,000.

In the area of invasive marine species, research capability has access to the department's $150,000 8-metre catamaran which is fitted with equipment to support divers and technicians in near-shore marine waters. Other marine craft, equipment, and on-shore facilities (e.g. tanks) valued at approximately $500,000 are used for experimental work and are, at times, accessed by biosecurity R&D staff. These facilities are located at Queenscliff.

DPI Vic manages a number of taxonomic collections which are considered priceless; 150,000 specimen invertebrate collection, 1500 specimen animal parasite collection, 8000 specimen plant parasitic nematodes collection, 35,000 specimen fungi collection, 1000 plant pathogenic bacteria collection, 500 specimen plant virus collection, 5000 animal histology slide collection, 80,000 specimen animal paraffin block collection, 44,000 specimen serum collection, 160,000 whole blood collection and a collection specifically dedicated to Johne's disease including 600 bacterial isolates, 400 faecal specimens and 350 fixed tissue samples.

Other infrastructure identified as priceless include the database of distribution maps of exotic marine species in Queenscliff and Bioweb, a web-based emergency surveillance and response platform at Attwood and Bendigo.

4.3.4. Qualitative survey – organisational focus

DPI Vic provided a response to the questionnaire covering all five biosecurity sectors.

Future increase in investment in DPI is likely to be found in development of diagnostic methodologies utilising systems biology (including barcoding); novel pest control methodologies, including endophytes, parasitoids, genetic control and sterile insects; development of surveillance tools, including semiochemicals, novel trap design and expert systems based on biological models; modelling the impacts of climate variability, extreme weather events, changing land use patterns, changing trade and transport pathways etc on biosecurity threats; and risk assessment to develop optimisation strategies for pest, disease and weed surveillance, intervention and eradication/containment/management decision making.

DPI Vic anticipates reduced R&D spending in areas associated with management strategies (Integrated Pest Management - IPM) for widely established pests and endemic weeds and investment in low priority endemic pests and diseases (indicated by absence of industry co-investment) e.g. vegetables. Areas which are likely to receive constant funding include control of high priority endemics (where industry co-invests), diagnostic capability for endemic, exotic and new and emerging pests and diseases and breeding for disease resistance, particularly in grains.

The organisation's top outputs in biosecurity R&D are a comprehensive and forward-looking Biosecurity Strategy for Victoria; product identification systems including the National Livestock Identification Scheme (NLIS); IT systems for collecting and managing biosecurity related data eg. MAX, YES, Live Trace, FlyBase; economic assessment model development and benefit cost analysis evaluations; epidemiological and outbreak predictive modelling; nationally endorsed rapid diagnostic protocols for regulated pests and diseases and key endemic diseases; community engagement in biocontrol programs; Integrated Pest and

Disease Management systems; risk analysis tools for weeds and animal diseases; and disease resistant plant varieties.

Areas in which the organisation takes a national or international leadership role include plant pest and disease diagnostics (diagnostic protocols and national systems); product identification systems including the NLIS; IT systems for collecting and managing biosecurity related data eg. MAX, YES, Live Trace; biosecurity aspects of climate change; and Integrated Pest Management programs for temperate crops. In addition, DPI Vic is program leader for Plant Biosecurity CRC, Chair of National Animal Health Laboratory System, Chair of Subcommittee Plant Health Diagnostic Standards and represents Australia on 2 QUADS working groups.

DPI Vic has international partnerships with MAF NZ (diagnostics), Michigan State University (Integrated Pest Management and pest modelling), Kansas State University (diagnostics) and International Center for Agricultural Research in Dry Areas (ICARDA), Syria (virus diagnostics), and has strong links with the CRCNPB.

DPI Vic identified their areas of excellence as animal epidemiology, disease diagnostic development and delivery, taxonomy, Integrated Pest Management systems for temperate crops, economic analysis, IT systems development and risk assessment.

4.4. Victorian Government: Department of Sustainability and Environment (Arthur Rylah Institute for Environmental Research)

4.4.1. Human capability

ARI Vic employs 6.9 FTEs in biosecurity R&D across the four biosecurity sectors of animal health, invasive animal species, invasive marine species and invasive weed species (Figure 37). Most (88%) are involved in invasive animal research, with animal health and invasive weeds accounting for4% and 6% of capability respectively and 1.5% in invasive marine species (Figure 37).

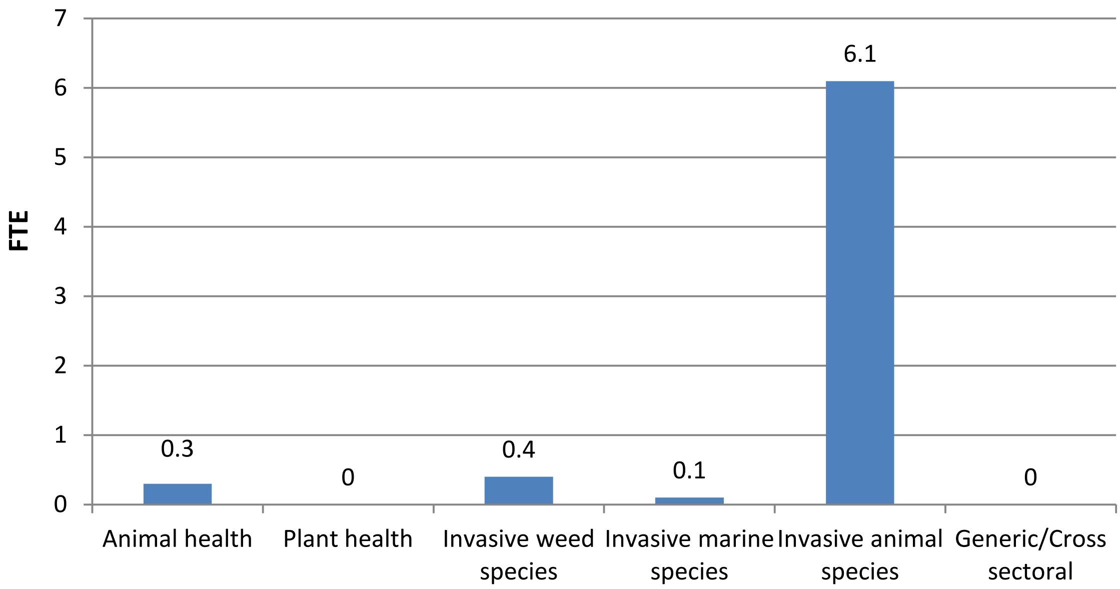

Figure 37. Full time equivalent (FTE) staff in biosecurity R&D by sector

Age

All biosecurity R&D capability in ARI was under 55 years of age. The cumulative distribution of age across the biosecurity sectors shows that 61% of capability was under 40 years of age, with the remainder (39%) between 40 and 55 years of age (Figure 38).

The trend was similar within the animal health, invasive animal species and invasive marine species sectors, with at least 60% of capability under 40 years of age (Figure 38). In the case of invasive marine species, 100% of capability was less than 40 years of age (Figure 38).

For invasive weed species, the trend was reversed with 75% of capability between 40 and 55 years of age and the remainder under 40 years of age (Figure 38).

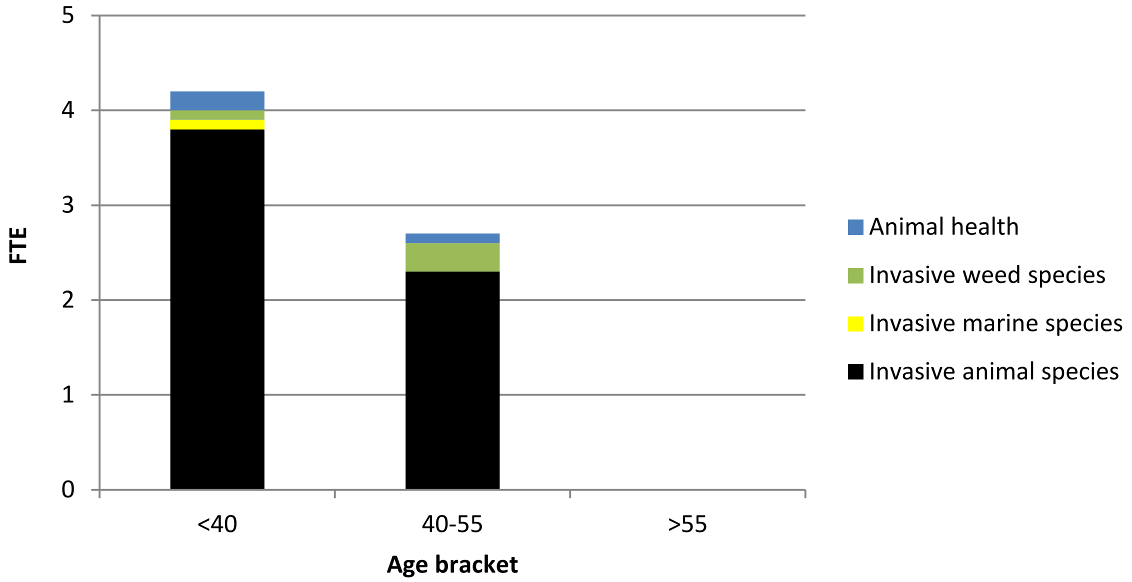

Figure 38. Full time equivalent (FTE) staff in biosecurity R&D by age bracket by sector

Research role

The predominant role in biosecurity R&D in ARI was researcher, accounting for 97% of research effort (Figure 39). Some technical support (3% of FTEs) was identified in the animal health and invasive animal species sectors, however neither postgraduate or postdoctoral research positions were identified (Figure 39).

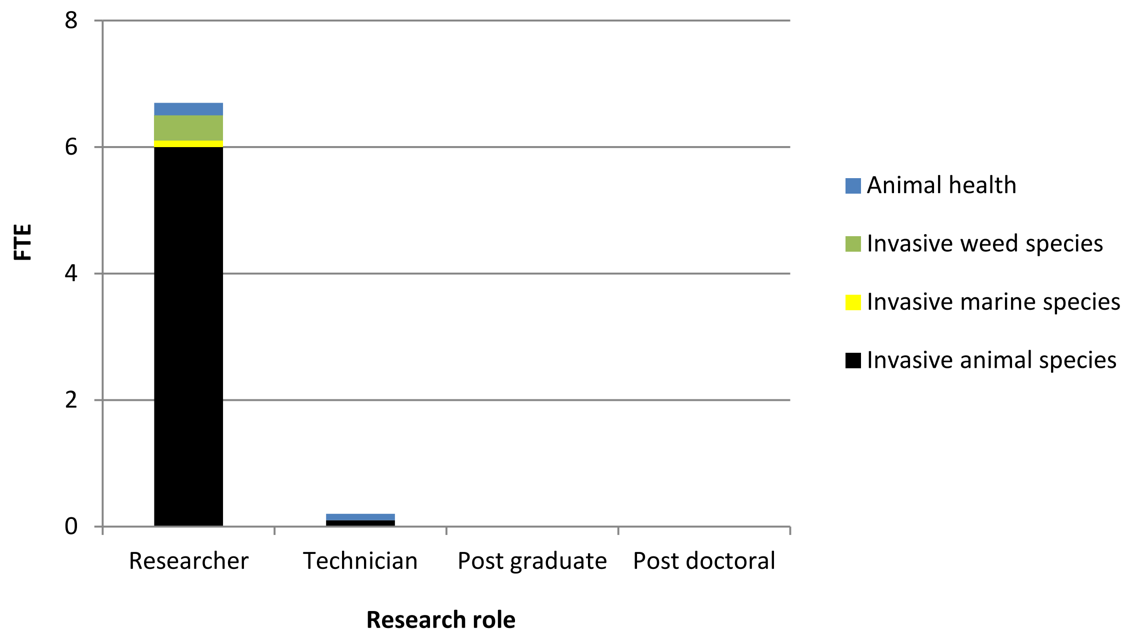

Figure 39. Full time equivalent (FTE) staff in biosecurity R&D by research role by sector

National biosecurity R&D priority area

The national biosecurity R&D priority areas and objectives are defined in Appendix C.

The data shows that ARI spends over 95% of effort on priorities 1 and 2, with 30% of effort on priority 1 and 67% on priority 2 (Figure 40). Three percent of effort was expended on priority 4 and none on priority 3. The most effort expended on a single objective was 39% on objective 2B (Figure 40).

Every sector expended effort on priorities 1 and 2, however only the invasive animal species sector conducted R&D against priority 4 (Figure 40). Invasive marine species expended all their effort against objective 1A and for animal health, all research effort was against objective 2C (Figure 40). Invasive weed species spent 25% of their effort on objective 1D and 75% on objective 2D (Figure 40).

Invasive animal species effort was applied 31% against priority 1, 66% against priority 2 and 3% against priority 4 (Figure 40). The single objective into which the invasive animal species sector put most effort (44%) was objective 2B (Figure 40). This was the only sector to invest in this objective (Figure 40).

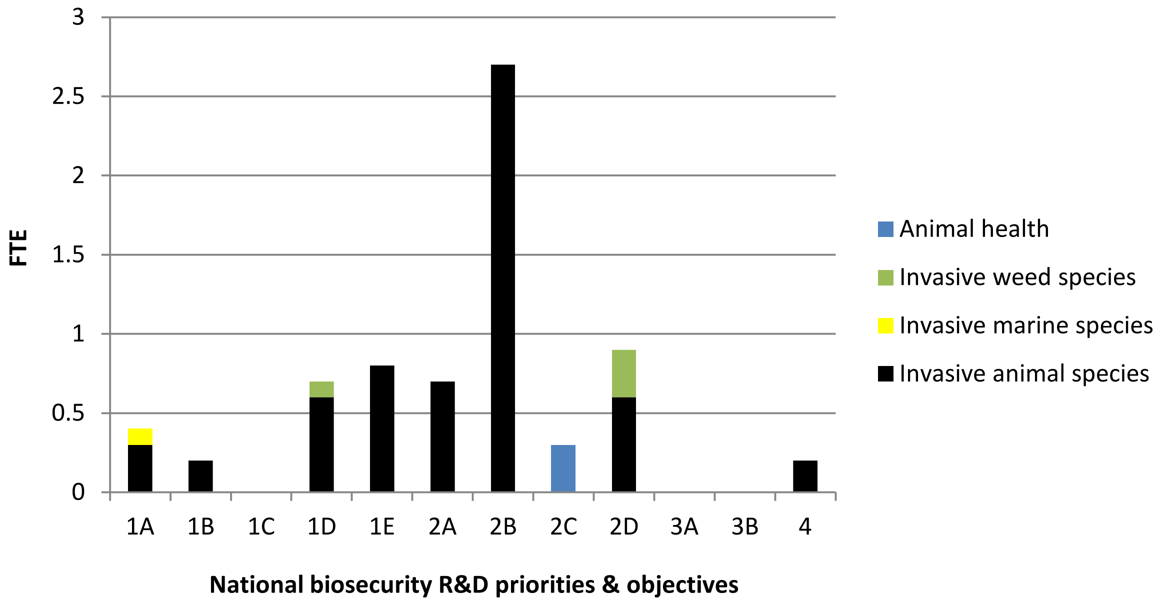

Figure 40. Full time equivalent (FTE) staff in biosecurity R&D by national priority/objective by sector

Discipline

The majority of effort was recorded against disciplines associated with invasive animal species (Table 21). The greatest capability was in the disciplines of population ecology (39%), ecology (13%), modelling/biometrics (12%), toxicology (12%) and risk analysis (9%; Table 21). All other disciplines accounted for less than 5 percent of effort each (Table 21)

Table 21. Full time equivalent (FTE) staff in biosecurity R&D by discipline

Sector	Discipline	FTE
Animal health	ecology	0.3
Invasive animal species	Population ecology	2.7
	Modelling/Biometrics	0.8
	Toxicology	0.8
	Ecology	0.9
	Spatial ecology	0.1
	Taxonomy	0.1
	Risk analysis	0.6
	Behavioural ecology	0.1
Invasive marine species	Ecology/taxonomy	0.1
Invasive weed species	Ecology	0.3
	Taxonomy	0.1
Total		**6.9**

4.4.2. Investment

Capability investment through wages

ARI spends approximately $559,455 per annum on wages for biosecurity R&D capability (Figure 41). Directly reflecting capability effort in FTEs, 88% of wages were paid to invasive animal species capability. Other sectors accounted for 7% (invasive weed species), 4% (animal health) and 1% (invasive marine species) of investment in biosecurity R&D capability (Figure 41).

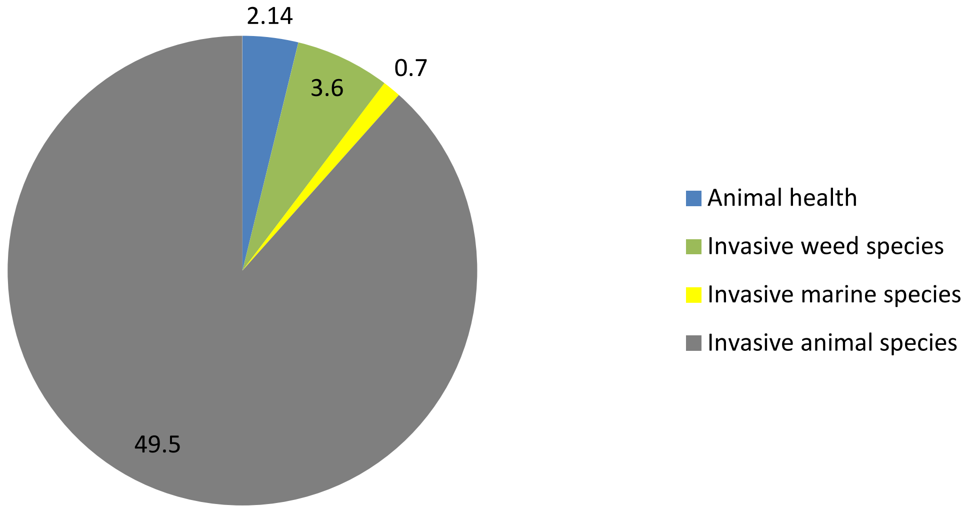

Figure 41. Investment in biosecurity R&D capability through wages (x $10,000)

External funding

ARI received $1,541,000 in external funding in 2011 and all of this was directed to the invasive animal species sector. Sources of external funding are listed in Table 22. The majority of funding was provided by the Australian and Victorian state governments. Some international funding was acquired.

Table 22. Sources of external investment for Biosecurity R&D in ARI

Biosecurity sector	Source of external investment
Invasive animal species	**Australian Government**
	Invasive Animals CRC
	DAFF
	State government
	Victoria DSE
	Parks Victoria
	Victoria DPI
	Other sources
	International

External funding for the invasive animal species sector was provided for fulfilment of R&D under priority 1 only, with $1,286,000 for objective 1D and $255,000 for objective 1E (Figure 42).

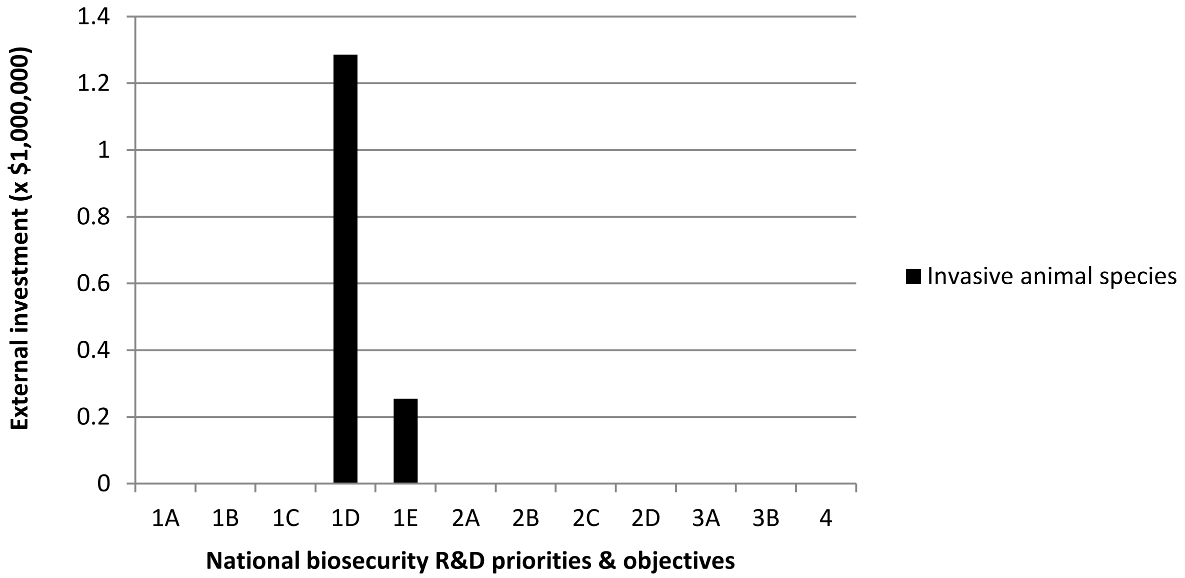

Figure 42. External investment in biosecurity R&D by priority/objective (x $1,000,000)

4.4.3. Infrastructure

ARI didn't identify any significant infrastructure investments or capital expenditure investments in the last 5 years or for the next 5 years.

4.4.4. Quantitative survey – organisational focus

The quantitative survey was completed by DSE and incorporated information about invasive animal species, invasive weed species and invasive marine species sectors.

DSE anticipates increasing R&D activity in the area of invasive animal species, especially management of vertebrate pest species, both terrestrial and aquatic. Research and development effort on invasive weed species and animal health will stay the same.

The organisation provides excellence in management of mammalian pests (monitoring, detection and eradication), epidemiology of bovine tuberculosis in wildlife, population ecology and dynamics of vertebrate pest species and management of invasive freshwater fish.

Subsequently, DSE's top biosecurity R&D outputs are surveillance strategies for wildlife pest species, population modelling, epidemiological modelling, and management and eradication strategies for vertebrate pests.

The department partners internationally with Landcare Research, New Zealand on vertebrate pest research and with Michigan Department of Natural Resources on wildlife tuberculosis research.

4.5. New South Wales Government: Department of Primary Industries

4.5.1. Human Capability

DPI NSW employs a total of 100.3 FTEs in biosecurity R&D across the biosecurity sectors. All sectors were represented, although there was no capability reported for generic/cross-sectoral R&D. Plant and animal health had the largest capability of the sectors (Figure 43).

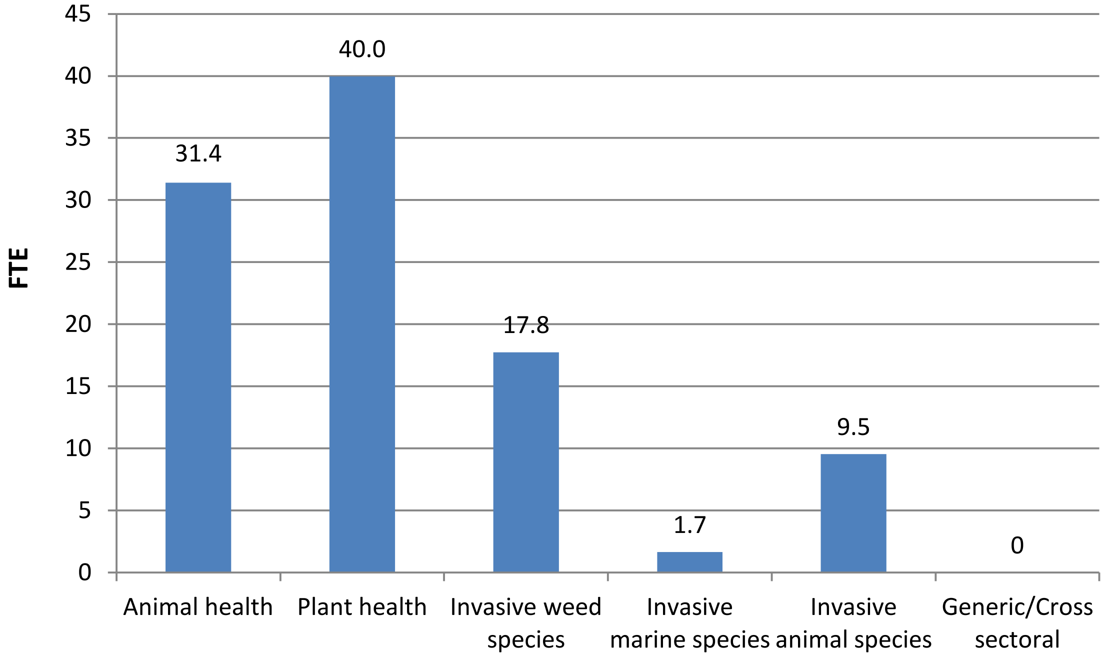

Figure 43. Full time equivalent (FTE) staff in biosecurity R&D by sector

Age

The cumulative age distribution across the biosecurity sectors shows that almost half the capability was between 40 and 55 years of age (Figure 44). Of the remaining capability, 30% were less than 40 and just over 20% were over 55 years of age (Figure 44).

The trend was similar for the plant health and invasive weed species sectors in which over half the capability was between 40 and 55 years of age (Figure 44). For plant health, 30% of the remaining capability was less than 40 and 15% were over 55 (Figure 44). For invasive weed species 15% of the remaining capability was less than 40 and 32% were over 55 (Figure 44).

For animal health there were similar levels of capability across the three age groups, however for invasive animal species the majority of capability (56%) was less than 40 years of age (Figure 44). The remaining capability was spread between those aged 40 to 55 years (33%) and those over 55 years of age (9%).

For invasive marine species the majority of capability (65%) was between 40 and 55 years of age (Figure 44). There were no staff over 55 years of age (Figure 44).

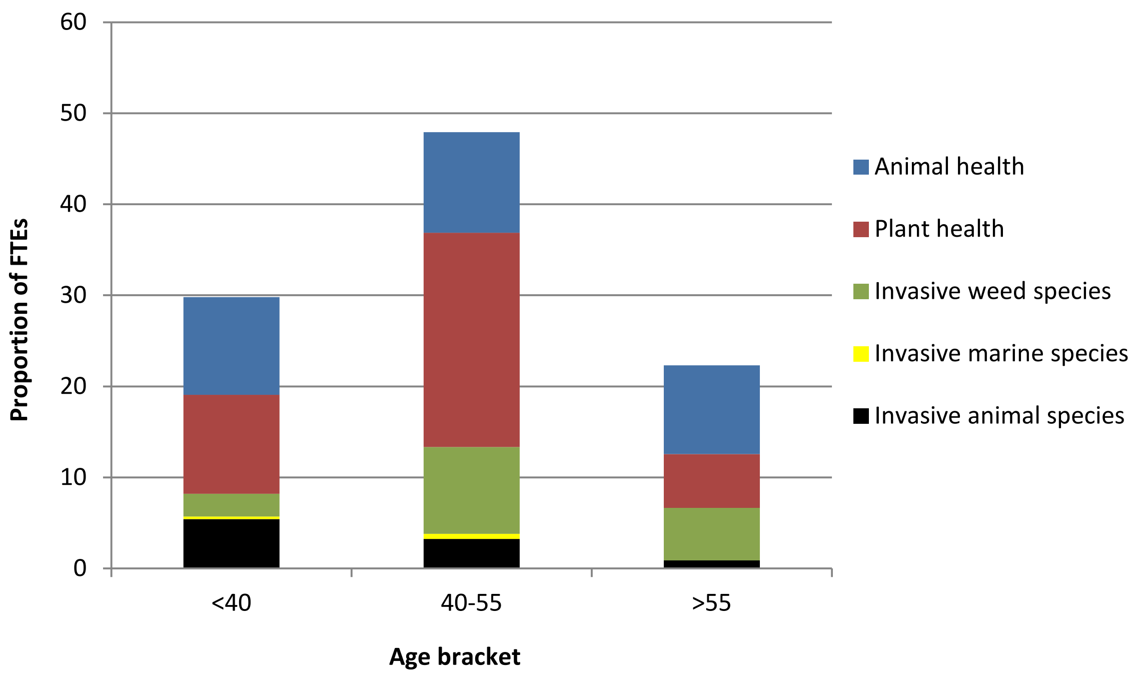

Figure 44. Proportion of full time equivalent (FTE) staff in biosecurity R&D by age bracket by sector

Note: Results given as a proportion to account for non-responses.

Research role

The predominant role in biosecurity R&D in DPI NSW was researcher, accounting for 55% of research effort, with the majority of remaining effort (44%) provided by technician support (Figure 45). There was no capability provided by postgraduates. In addition, postdoctoral researchers accounted for only 1% of researchers and all this capability was in the invasive animal species sector (Figure 45). For this sector postdoctoral researchers represented 10% the research population (Figure 45).

There were approximately twice the number of FTEs against researchers compared to technicians for the plant health, invasive weed species and invasive animal species sectors (Figure 45). An opposite trend was observed for animal health and invasive marine species in which there was greater technical capability than researcher capability. For animal health there were 1.6 fold more technicians than researchers and for invasive marine species 2.6 fold more technicians (Figure 45).

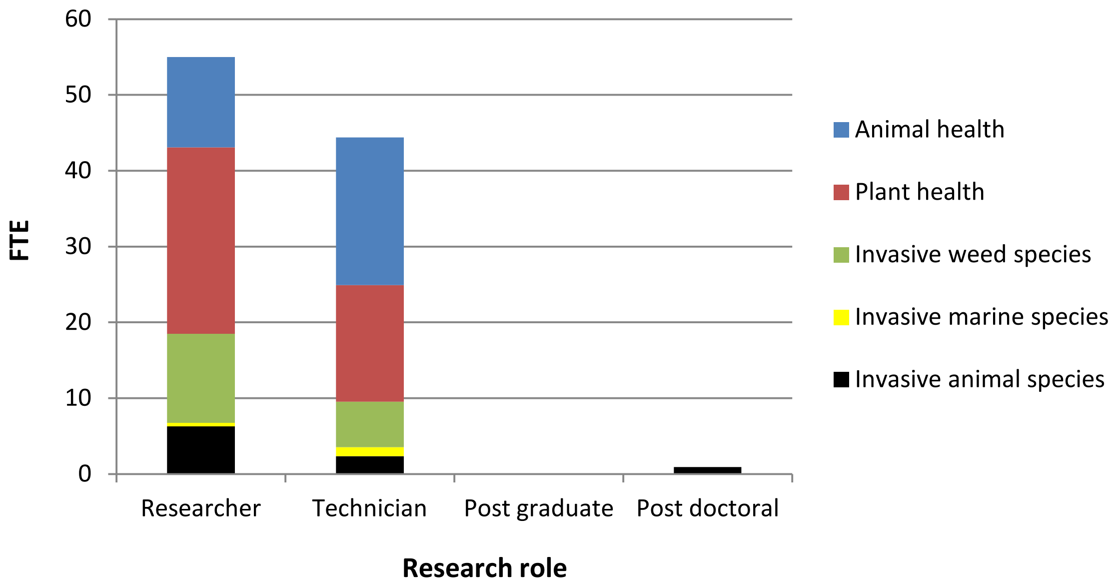

Figure 45. Full time equivalent (FTE) staff in biosecurity R&D by research role by sector

National biosecurity R&D priority areas

FTEs were collected against the national biosecurity priority areas. The data shows that DPI NSW spends over 87% of effort on priorities 1 and 2 with approximately 77% of that effort invested in objectives 1E and 2B (Figure 46). All sectors conducted R&D against these two priorities except for invasive marine species (Figure 46). The only objectives in which all sectors conducted R&D were 1A and 1B, although for some sectors the FTEs spent on these areas were very low (Figure 46).

Priority area 1 accounted for 50% the total research effort across all the priorities (Figure 46). Within this priority area, the majority of research effort (40%) was against objective 1E and all sectors except invasive marine species conducted R&D against this objective (Figure 46).

Priority area 2 accounts for 37% the total research effort across all the priorities (Figure 46). Within this priority area, the majority of research effort (77%) was against objective 2B and all sectors except invasive marine species conducted R&D against this objective (Figure 46). Plant health, invasive weed species and invasive animal species all conducted research against objective 2A which accounted for 3% the research effort against priority 2 (Figure 46). Animal health, plant health and invasive weed species all conducted R&D against objective 2C, and all sectors except animal health conducted R&D against objective 2D. Together these objectives accounted for 20% the research effort against priority 2 (10% each; Figure 46).

Only 5% of total research effort was against priority area 3 and this effort was fairly evenly spread between objectives 3A and 3B (Figure 46). Invasive weed species, invasive marine species and invasive animal species all conducted R&D against objective 3A and animal health and invasive weed species conducted R&D against objective 3B (Figure 46).

Only 8% of research effort was conducted against priority 4 and the majority of this research (89%) was conducted by the animal health sector (Figure 46). The remaining 11% was conducted by the invasive animal species sector (Figure 46).

Looking at the sectors individually, animal health conducted biosecurity R&D across priority areas 1 to 4, with the majority of R&D occurring against objective 2B (40%). However, no FTEs were spent against objectives 1C, 1D, 2A, 2D or 3A (Figure 46).

Plant health conducted R&D against all the priorities except 4, and all objectives except for 1C, 3A and 3B (Figure 46). The majority of R&D was against objectives 1E (28%) and 2B (34%; Figure 46).

Invasive weed species R&D was conducted across all the priorities and objectives except for priority area 4 (Figure 46). The majority of time was spent against objectives 1A (24%) and 2D (16%).

Invasive marine species conducted R&D against priorities 1, 2 and 3, however only objectives 1A, 1B, 2D and 3A were covered (Figure 46). Of these objectives, the majority of time (50%) was spent against 3A. No R&D was conducted against priority area 4 (Figure 46).

Invasive animal species had fairly good coverage across the priority areas and objectives with only objectives 2C and 3B not covered by any FTEs (Figure 46). The majority of FTEs for this sector (40%) were against objective 1A (Figure 46).

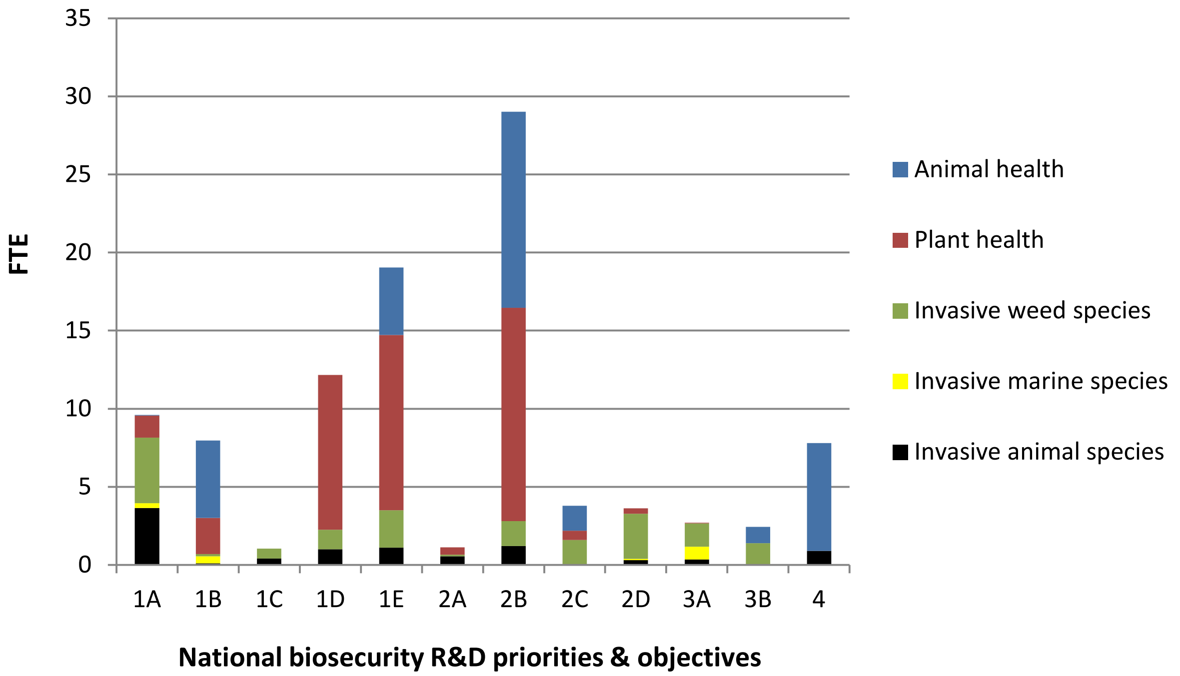

Figure 46. Full time equivalent (FTE) staff in biosecurity R&D by priority/objective by sector

Discipline

FTEs were collected against disciplines (Table 23). For animal health the majority of FTEs were in the discipline of virology (63%). For both plant health (35%) and invasive weed species (48%) the greatest capabilities were in the discipline of entomology (Table 23). For the invasive marine species sector, the majority of capability (71%) was in ecology and for invasive animal species the greatest capabilities were in the disciplines of biological control (19%), pest control (19%) and population control (19%; Table 23).

Table 23. Full time equivalent (FTE) staff in biosecurity R&D by discipline

Biosecurity sector	Discipline	FTEs
Animal health	Anatomical pathologist	0.1
	Immunology	1.9
	Virology	19.8
	Bacteriology	7.2
	Epidemiology	0.8
	Parasitology - ectoparasitology	0.8
	Veterinarian	0.8
Plant health	Acharology	0.2
	Auditing in biosecurity	0.5
	Bacteriology	1.5
	Biometrics	0.1
	Disease & pest resistance	5.4
	Entomology	14.4
	GIS	0.1
	Microscopy	0.1
	Modelling	0.2
	Mycology	6.2
	Pathology	9.3
	Risk analysis	0.4
	Soil microbial ecology	0.2
	Surveillance	0.3
	Virology	0.8
	Nematology	0.4
Invasive weed species	Entomology	0.9
	Agronomist	8.6
	Risk Analysis	1.9
	Biological Control	4.6
	Herbicide Application	1.8
Invasive marine species	Ecology	1.2
	Modelling	0.1
	Surveillance	0.4
Invasive animal species	Behavioural ecology	0.9
	Biological control	1.8
	Modelling	0.9
	Pest control	1.8

	Population ecology	1.8
	Surveillance	0.9
	Toxicology	1.4
Total		**100.3**

4.5.2. Investment

Capability investment through wages

DPI NSW spends approximately $8,468,762 per annum on wages for biosecurity R&D capability across the various sectors. Approximately 40% of this amount was invested in wages for the plant health sector, 30% for the animal health sector, 18% for invasive weed species, 11% for invasive animal species and only 0.4% for invasive marine species (Figure 47).

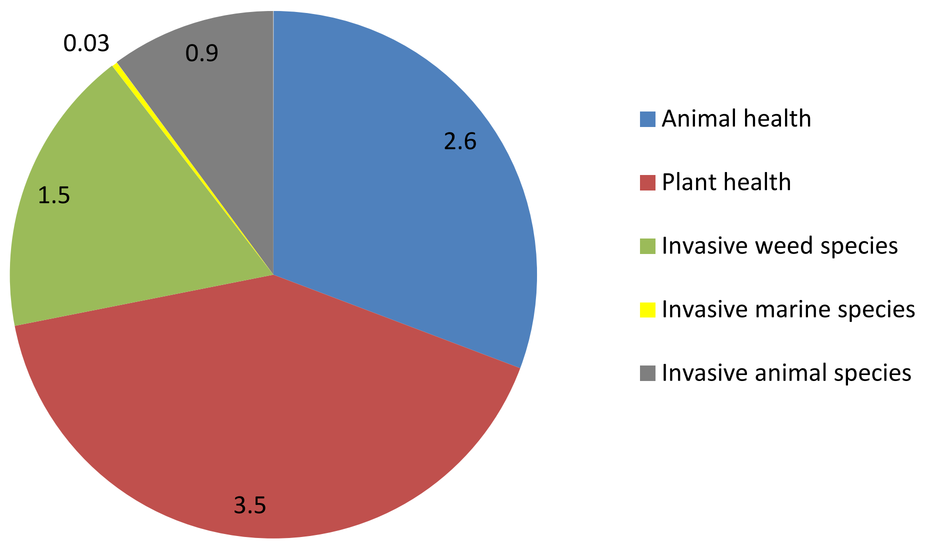

Figure 47. Investment in biosecurity R&D capability through wages (x $1,000,000)

External funding - amounts

The department received external funding in 2011 amounting to $12,639,600. Plant health received the greatest amount of external funding, representing almost 70% the total amount invested across the sectors (Figure 48). Invasive animal species received more external funding than animal health (14% compared to 11% respectively). Invasive weed species received 7% the total amount externally invested across the sectors and invasive marine species received only 1% (Figure 48).

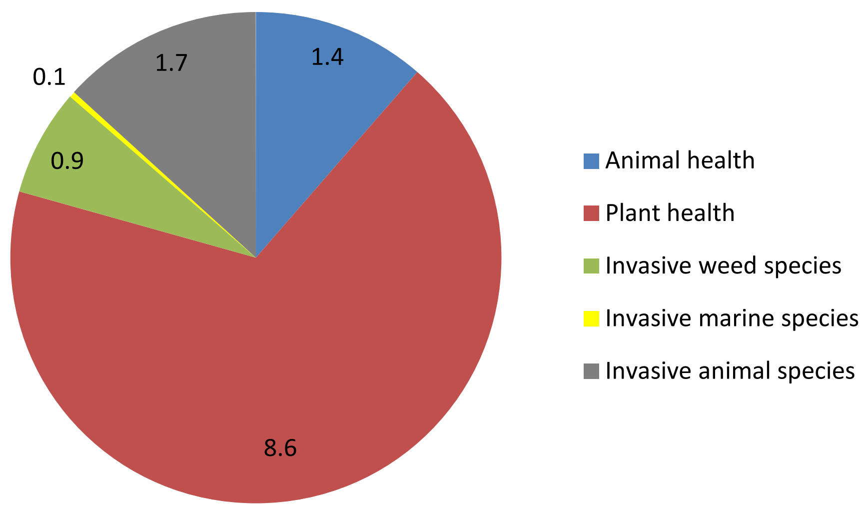

Figure 48. External investment in biosecurity R&D by sector (x $1,000,000)

External funding - sources

Sources of external investment (for 2011) were varied (Table 24). Some of the major investors for plant health included ACIAR, RIRDC and HAL, for animal health, MLA and the University of Sydney, for invasive weed species, GRDC, the Cotton CRC and RIRDC and for invasive animal species, the Invasive Animals CRC and Caring for our Country were the greatest investors. For invasive marine species, external funding was provided by miscellaneous government contributions.

Table 24. Sources of external investment for Biosecurity R&D in DPI NSW

Biosecurity sector	Source of external investment
Animal health	**Australian Government**
	DAFF
	Pork CRC
	Invasive Animal CRC
	Rural RDCs
	MLA
	Australian Pork Limited
	RIRDC
	AWI
	Universities
	University of Sydney
	University of Queensland
	Private Industry
	International Animal Health Products

	Centre for Digestive Diseases
	Other sources
	Animal Health Australia
	McGarvie Smith Institute
	Hermon Slade Foundation
Plant health	**Australian Government**
	Environmental Trust
	CRCNPB
	CSIRO
	ACIAR
	Cotton Catchment Communities CRC
	DAFF
	State Government
	NSW DPI
	Rural RDCs
	Cotton RDC
	GRDC
	RIRDC
	HAL
	Universities
	Charles Sturt University
	Commercial industry
	DuPont
	Other Industry sources
	Applied Horticulture Research
Invasive weed species	**Australian Government**
	Caring for our Country
	DAFF (Weeds of National Significance)
	Cotton CRC
	State Government
	Qld DAFF
	RDC funds
	Rural Industries RDC
	GRDC
	Universities
	University of Adelaide

Invasive animal species	**Australian Government**
	Invasive Animals CRC
	DAFF (Australian Pest Animal Research Program)
	Caring for our Country
	State Government
	NSW Weeds Program
	Rural RDCs
	MLA
	Australia Wool Innovation
	Rural Industries RDC
	Private Industry
	Newmont Mining
Invasive marine species	Miscellaneous Government contributions

External funding – against priority area

External funding by national biosecurity R&D priorities and objectives shows that the major investment across the sectors was in objective 2B (Figure 49). All the sectors conducting biosecurity R&D were externally funded against this objective, which also received the greatest amount of external funding for all sectors excluding plant health (Figure 49). For plant health, objective 1E received the largest amount of external funding (Figure 49).

Plant health also had the greatest external investment coverage across the priority areas and objectives, however objectives 1C, 2C, 3A and priority 4 were not externally funded at all (Figure 49). In contrast invasive weed species and invasive marine species only received external funding against objective 2B and animal health only against objectives 1E, 2B and priority 4 (Figure 49).

None of the sectors were funded externally for objective 1C (Figure 49). Plant health was the only sector which received funding for objectives 1A and 1D, and invasive animal species was the only sector to receive external funding for 2C and 3A, and animal health was the only sector with external funding against priority area 4 (Figure 49).

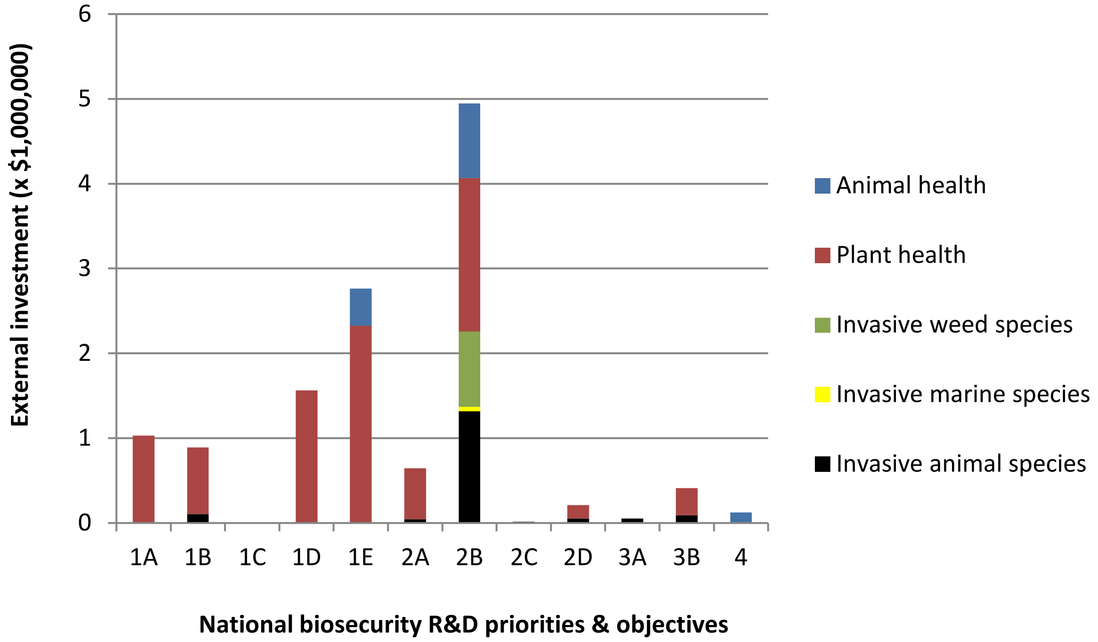

Figure 49. External investment in biosecurity R&D by priority/objective by sector

4.5.3. Infrastructure

Infrastructure investments for DPI NSW in the last 5 years (2007 – 2011) included an upgrade of EMAI (Plant and Animal Biosecurity R&D) in Menangle NSW at a cost of $57,000,000, Central Coast Primary Industries Centre Gosford at $8,500,000 and greenhouses at Wagga Wagga Agricultural Institute totalling $900,000.

Infrastructure investments forecast for the next 5 years (2012 – 2016) include the continued development of the Central Coast Primary Industries Centre Gosford with predicted cost of $2,000,000.

Capital expenditure on equipment for the last 2 years (2010 – 2011) that is not captured in infrastructure investments included $776,273 for plant health, $580,412 for animal health, $14,344 for invasive animal species, $97,100 for invasive weed species and $61,726 for invasive marine species.

The key national biosecurity R&D infrastructure identified by DPI NSW includes the Domestic Animal Pathology Registry and QC2 and QC3 laboratories at EMAI, as well as the Australian Scientific Collections Unit at Orange.

4.5.4. Qualitative survey – organisational focus

DPI NSW provided one response to the questionnaire covering animal health, plant health, invasive weed species, invasive animal species and invasive marine species.

Future investment in biosecurity R&D is expected to increase at sites where DPI has recently invested in significant new infrastructure for biosecurity R&D – particularly EMAI and Ourimbah.

DPI NSW may seek to redirect existing core-funded research staff to increase R&D focus on the following areas:

- Development and validation of new methods and tools delivering high volume fast turnaround techniques for surveillance and diagnostics, including in-field test kits for front line testing and preparedness for exotic diseases of animals, plants and aquatic organisms utilizing the new QC3 facilities at EMAI
- Whole genome analyses as a means of providing a faster identification of pests
- Diagnostic tests and treatments for endemic diseases where the technology can be leveraged to emerging and exotic diseases

DPI NSW anticipates increasingly strong partnerships in future with universities and the commercial sector.

It is also anticipated that there will be some reduction in external funding for R&D in coming years which will manifest as a reduction in available salaries, and therefore reduced FTEs for technical support staff.

Future investment in biosecurity R&D that is expected to remain the same includes commitment to a comprehensive range of research capability to meet a wide range of threats relevant to NSW. In addition commitment to development of new techniques through research relevant to detection, containment and eradication of exotic and endemic pests.

The Department's top ten outputs in biosecurity R&D include:

- Development of new diagnostic tests for exotic and endemic pests, e.g.
    - Livestock - Bluetongue virus, Lawsonia in pigs, Pestivirus in cattle, Johne's disease, including zoonotics such as Strep suis
    - Plants – pathovars of Xanthomonas in citrus, cotton and brassicas, citrus viruses, fungal diseases of crops, resolution of species complexes e.g. *Bactrocera dorsalis*
- Development of new technologies to enhance management of established biosecurity threats, for example
    - Development of novel vaccines e.g. Lawsonia in pigs.
    - Development of integrated pest management systems and biopesticides for the horticultural and cotton industries
    - Development of mild strain cross protection strategy to protect the citrus industry against stem pitting by Citrus tristeza virus
    - Harbourage trap for Small Hive Beetle
    - Development of new techniques for the management of phosphine resistance including extending the life of phosphine fumigants in stored grain pests
    - Evaluation of new Rabbit Haemorrhagic Disease Virus (RHDV) strains to strengthen rabbit biocontrol
    - Pests and weeds
- Development of cross jurisdictional diagnostic protocols such as the National Diagnostic Protocols for Citrus canker, Russian wheat aphid, Karnal bunt etc
- Research to better define new and emerging diseases and to define the potential native reservoirs for exotic pests and diseases e.g.

    - Arboviral diseases in horses in south east Australia, Theileriosis in beef and dairy cattle.
    - Identification of Australian native plants that may harbour the glassy winged sharp shooter and of other insects that may vector *Xylella fastidiosa*

DPI NSW provides international leadership roles in the following:

- General
    - Capacity building through international aid programs, scholarships and collaboration
    - Quality Assurance – all diagnostic labs are National Association of Testing Authorities (NATA) accredited and research labs ISO 9001 certified
- Animal Biosecurity
    - Viral diseases of livestock
    - Bee disease diagnostics
    - Molecular diagnostics for bacterial diseases of pigs
- Plant Biosecurity
    - IPM in horticulture and cotton
    - Market access and greenhouse horticulture
    - Molecular diagnostics
    - Rust pathology
    - Biopesticides
- Invasive Species
    - Invasive animal management

DPI NSW has extensive international partnerships in biosecurity R&D. These currently include strong collaboration with a number of Universities and Agencies/Institutes in USA, Europe and New Zealand related to:

- virus disease research (e.g. Pestivirus, Arbovirus, Calicivirus)
- pest animal control
- plant health research

There is also extensive collaboration with SE Asia in particular Indonesia, Philippines, Thailand and Vietnam.

DPI NSW identified their areas of excellence as:

- Quality management systems – NATA in diagnostic laboratories, ISO 9001 in research laboratories
- Biological control of weeds
- Humane pest animal control
- International leadership roles as mentioned above

4.6. Tasmanian Government: Department of Primary Industries, Parks, Water and Environment

4.6.1. Human Capability

DPIPWE employs 7.3 FTEs in biosecurity R&D exclusively in the animal health sector.

Age

The age distribution shows that almost half the capability (48%) was less than 40 years of age (Figure 50). Of the remaining capability, 41% was between 40 and 55 years of age and 11% were over 55 years of age (Figure 50).

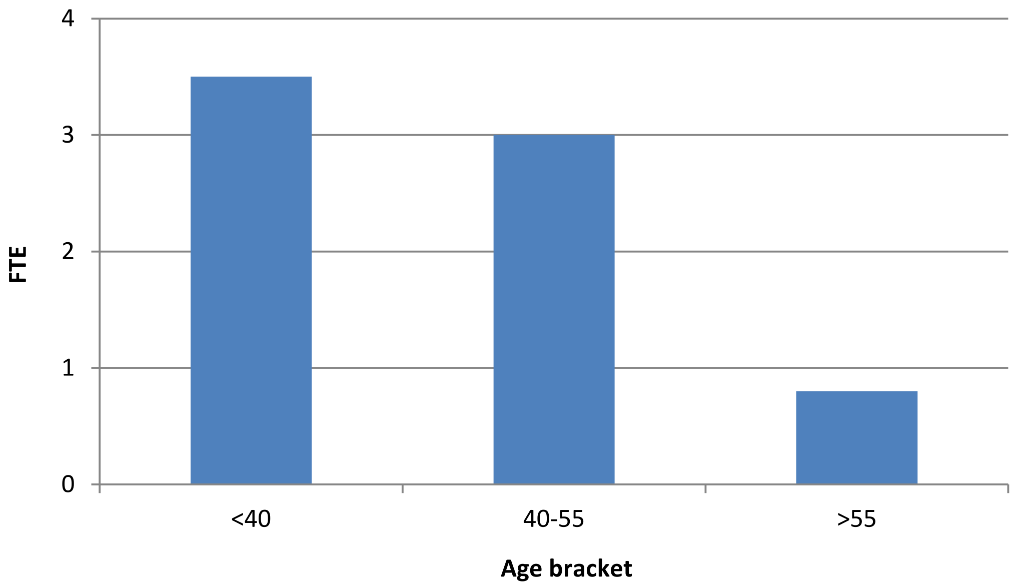

Figure 50. Full time equivalent (FTE) staff in biosecurity R&D by age bracket

Research role

The predominant role in biosecurity R&D in DPIPWE was researcher, accounting for 67% of research effort, with the majority of remaining effort (30%) provided by technical support (Figure 51). Almost 3% of capability was provided by postgraduates, however no capability was provided by postdoctoral researchers (Figure 51).

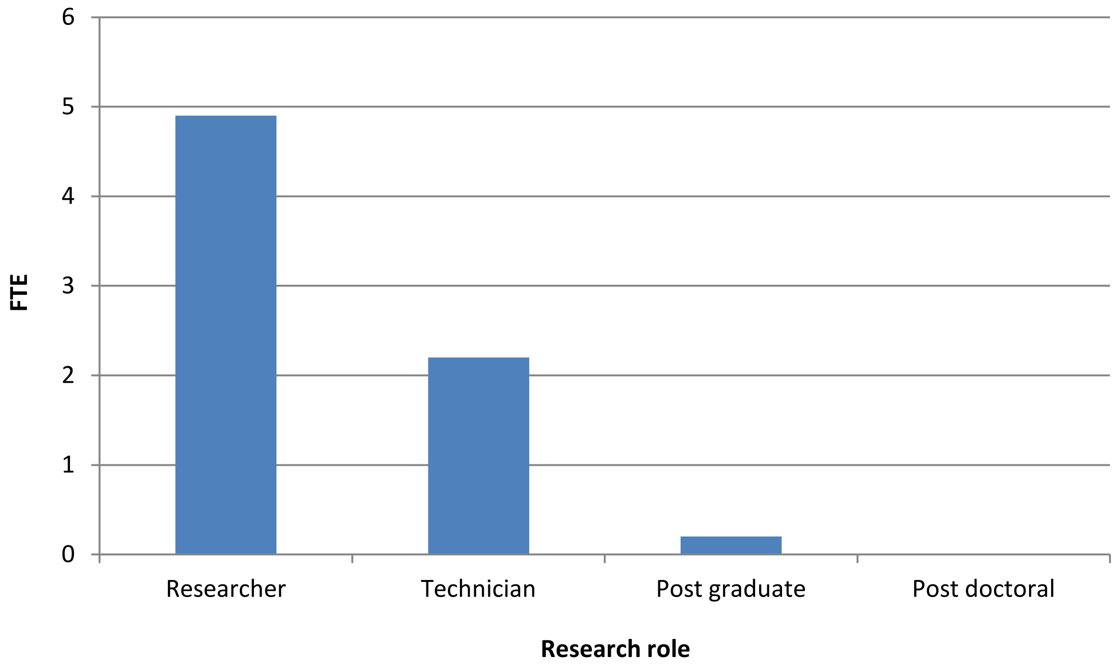

Figure 51. Full time equivalent (FTE) staff in biosecurity R&D by research role

Capability against priority area

FTEs collected against the national biosecurity R&D priorities and objectives (see Appendix C) shows that DPIPWE spends all of its R&D effort against priority 1 (Figure 52). Most effort (57%) was spent on objective 1E, followed by 27% on objective 1A and 16% on objective 1B (Figure 52). No effort was expended against priority areas 2, 3 or 4 (Figure 52).

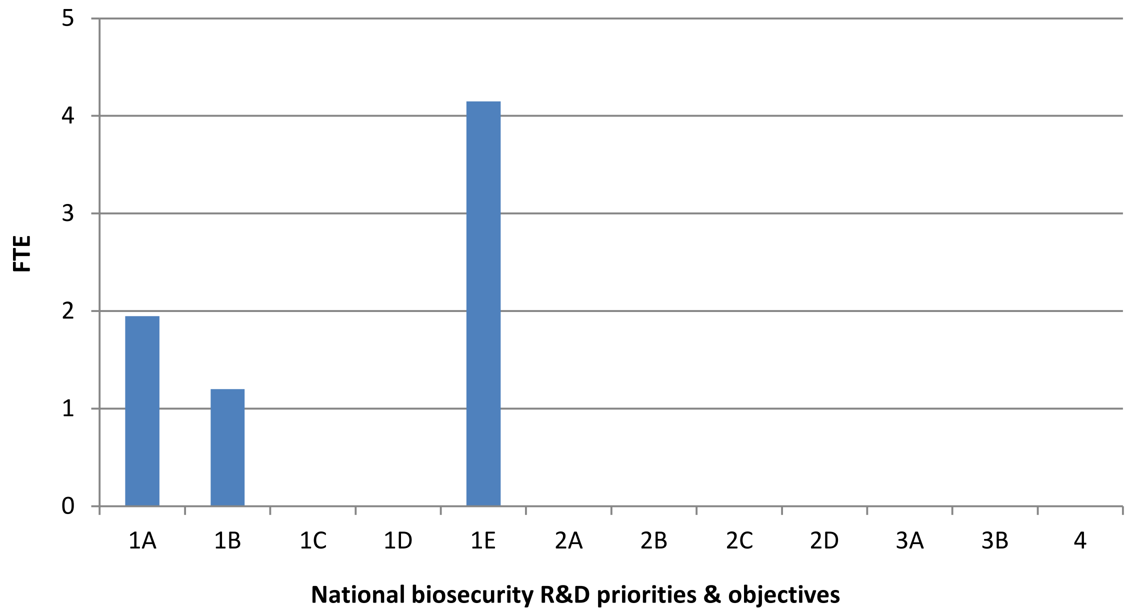

Figure 52. Full time equivalent (FTE) staff in biosecurity R&D by priorities and objectives

Discipline

The majority of capability in DPIPWE was in the disciplines of animal science (45%) and immunology (44%; Table 25).

Table 25. Full time equivalent (FTE) staff in biosecurity R&D by discipline

Biosecurity sector	Discipline	FTEs
Animal health	Anatomical pathologist	0.6
	Immunology	3.2
	Animal scientist	3.3
	Bacteriology	0.2
Total		**7.3**

4.6.2. Investment

Capability investment through wages

DPIPWE spends approximately $543,326 per annum on wages for biosecurity R&D capability in the animal health sector.

External funding

The department received $1,150,000 in external funding for biosecurity R&D in 2011. Major investors of R&D were The Australian Government through DAFF and RDCs, the Tasmanian Government and aquatic animal industries, either directly or through RDCs (Table 26).

Table 26. Sources of external investment for Biosecurity R&D in DPIPWE, Tasmania

Biosecurity sector	Source of external investment
Animal health	**Australian Government**
	DAFF
	State Government
	DPIPWE Tasmania
	Rural RDCs
	FRDC
	Other Industry sources
	Tasmanian Salmon Growers Association
	Tasmanian Oyster Industry

External funding by priorities (see Appendix C) shows that the majority of funding (75%) was spent against priority 1, on objectives 1A, 1B and 1E (Figure 53). Although no research effort was spent against objective 2A (Figure 52), 25% of external funds went towards this objective (Figure 53).

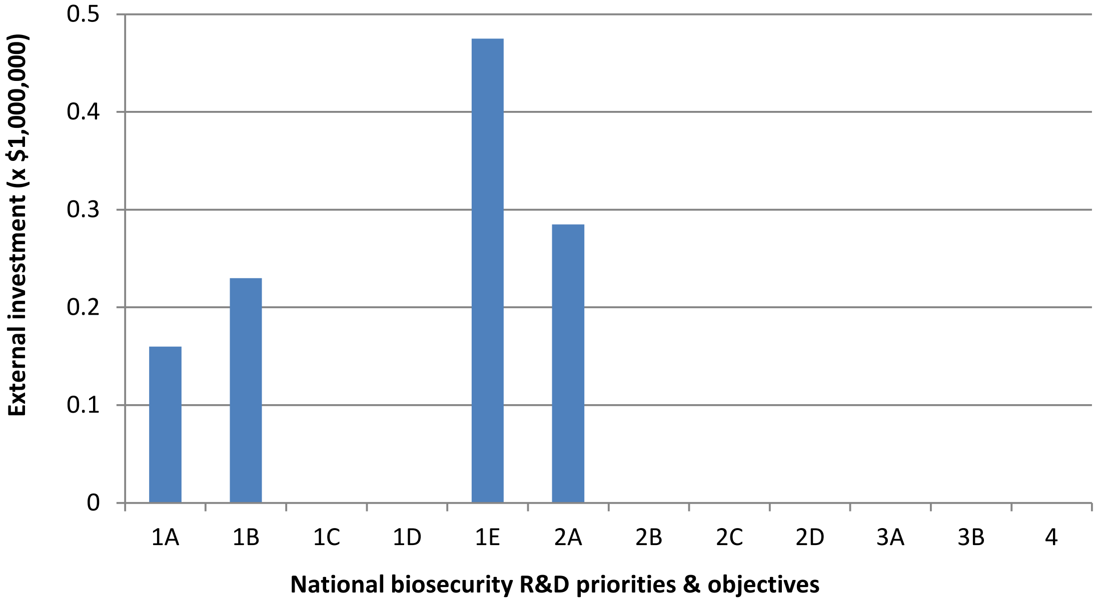

Figure 53. External investment in national biosecurity R&D priorities and objectives

4.6.3. Infrastructure

DPIPWE investment in biosecurity R&D infrastructure in the last 5 years (2007 – 2011) included an aquarium facility for vaccine research valued at $130,000 and AB 7500 RT PCR and associated equipment worth $170,000.

Investment for the next 5 years was not able to be estimated for this exercise.

An emergency power generation source ($70,000) was purchased as part of capital expenditure on equipment that was not captured in infrastructure investments.

Tasmania identified the ABIN Vetpath node, the Animal Health Laboratory (AHL), the AHL bacterial culture collection, and the devil facial tumour disease BAC library as key national R&D infrastructure. All are based in Launceston.

4.6.4. Qualitative survey – organisational focus

The qualitative survey was completed by AHL on behalf of DPIPWE.

AHL anticipates that future investment in biosecurity R&D will increase in the area of industry partnership to support market access and assurance for targeted disease, vectors and hosts. Research into devil facial tumour disease will decrease and DPIPWE will maintain diagnostic investigation services to support passive surveillance efforts.

DPIPWE (AHL) provides a national leadership role in research into fish vaccines and veterinary diagnostics. AHL's major outputs are salmonid vaccines and devil facial tumour research. In addition, they provide numerous, more minor, outputs to support local programs and investigations.

4.7. South Australian Government: Department of Primary Industries and Regions, SA (South Australian Research and Development Institute)

4.7.1. Human Capability

PIRSA employs a total of 33.4 FTEs in biosecurity R&D across the biosecurity sectors. All sectors were represented although there was no capability reported for generic/cross-sectoral R&D (Figure 54). Plant health had the largest capability of the sectors (Figure 54).

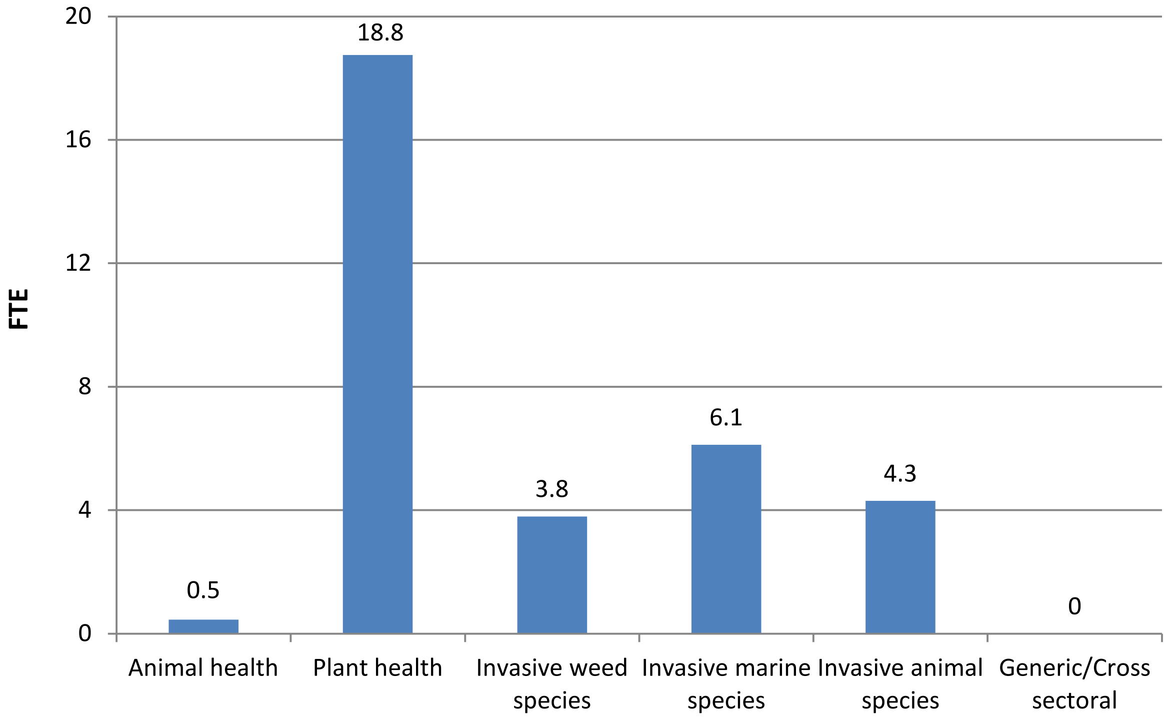

Figure 54. Full time equivalent (FTE) staff in biosecurity R&D by sector

Age

The age distribution across the biosecurity sectors shows that almost all the capability was spread fairly evenly between those aged less than 40 and those between 40 and 55 years of age (Figure 55). Only a very small percentage of capability (0.04%) was over 55 years of age (Figure 55).

The trend was similar for the plant health sector, however for invasive weed species 80% of the capability was between 40 and 55 years of age and all the remaining capability was less than 40 (Figure 55).

For the animal health sector, all the capability was less than 40 years of age (Figure 55). In contrast, invasive animal species had capability spread between all age groups, with the majority (60%) between 40 and 55 years of age and the remainder spread between those less than 40 (23%) and those over 55 years of age (17%; Figure 55).

For invasive marine species the majority of capability (93%) was less than 40 years of age and the remaining (7%) were between 40 and 55 years of age (Figure 55).

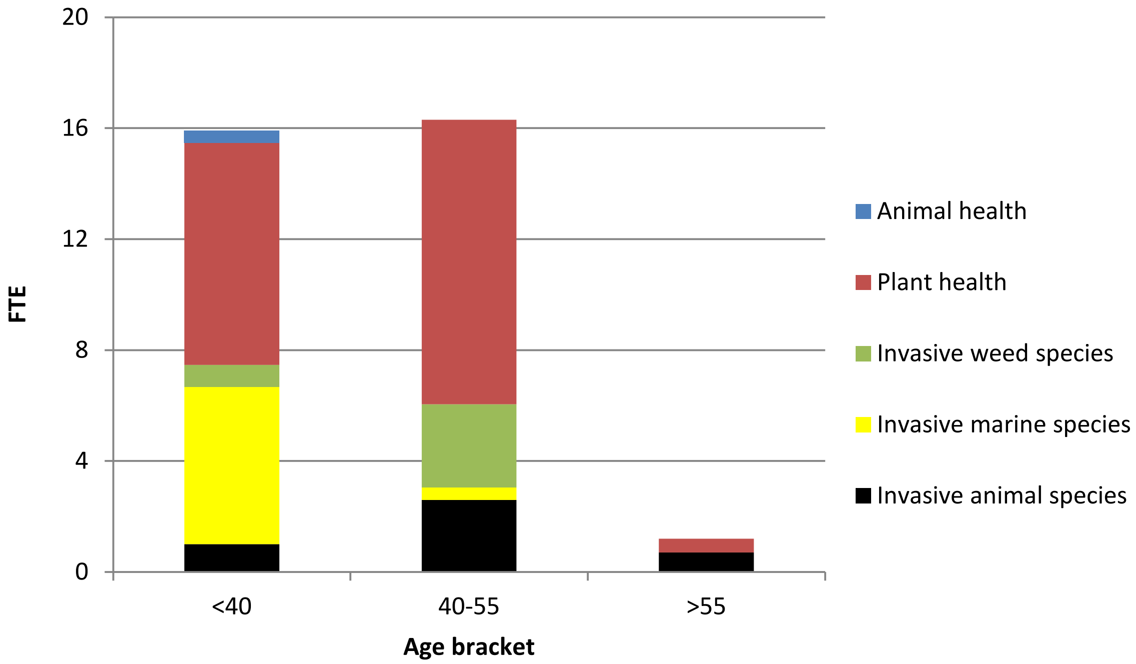

Figure 55. Full time equivalent (FTE) staff in biosecurity R&D by age bracket by sector

Research role

The predominant role in biosecurity R&D in PIRSA was researcher, accounting for 73% of research effort, with the majority of remaining effort (24%) provided by technical support (Figure 56). Only 3% of capability was provided by postgraduates and there were no postdoctoral researchers (Figure 56).

There were 3-fold more FTEs against researchers compared to technicians for the plant health and invasive weed species sectors and 9-fold more researchers than technicians in the invasive marine species sector (Figure 56). However for invasive animal species there was approximately the same number of FTEs for researchers and technicians (Figure 56). For animal health all FTEs were in the researcher category (Figure 56).

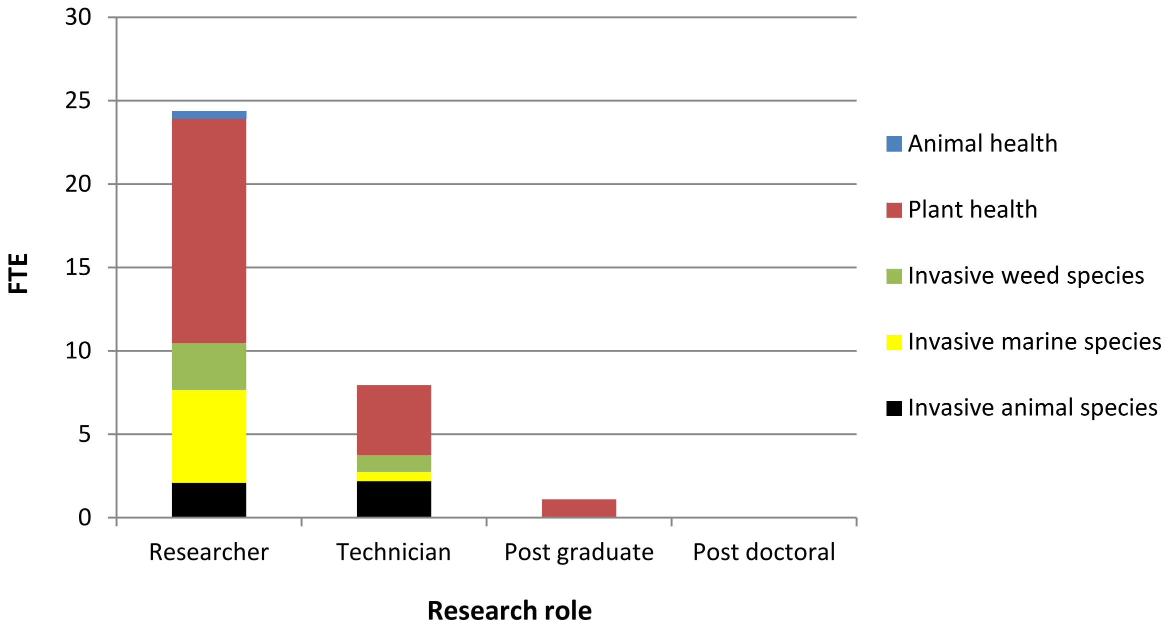

Figure 56. Full time equivalent (FTE) staff in biosecurity R&D by research role by sector

Capability against priority area

FTEs were collected against the national biosecurity priority areas. The data shows that PIRSA conducted R&D against all the priority areas and objectives except 1C (Figure 57). The greatest FTEs were spent against priority 2 (61%) and approximately 71% of that effort was invested against objective 2B (Figure 57). In addition, plant health conducted the majority of R&D (66%) against this objective, with the remaining conducted by invasive weed species, invasive marine species and invasive animal species (Figure 57).

Priority area 1 accounted for 27% the total research effort across all the priorities (Figure 57). Within this priority area, the majority of research effort (40%) was against objective 1A (Figure 57). Plant health conducted 71% of the R&D against this objective with the remaining spread between animal health (3%) and invasive marine species (26%; Figure 57).

Only 6% of the total research effort was against priority area 3 and approximately 80% of that effort was invested in objective 3A (Figure 57). The only sectors conducting R&D against priority area 3 were the invasive marine species and invasive animal species sectors (Figure 57). Invasive animal species conducted the majority (77%) of R&D against objective 3A whereas invasive marine species conducted all the R&D against objective 3B (Figure 57).

The total research effort invested in priority area 4 was 6% and 68% of this R&D was conducted by the plant health sector (Figure 57). The remaining was conducted by the invasive weed species (24%) and invasive marine species (8%) sectors (Figure 57).

Looking at the sectors individually, animal health conducted biosecurity R&D against priority area 1 only (Figure 57). In contrast, plant health conducted R&D across all priority areas except 3, with the majority of R&D against objective 2B (50%). Similarly, invasive weed species R&D was conducted across all the priorities except 3, with the majority of time (58%) spent against objective 2B (Figure 57). Invasive marine species conducted R&D against all the priorities and the only objectives in which no R&D was conducted were 1C and 1E

(Figure 57). Invasive animal species conducted R&D against priorities 1, 2 and 3, with the greatest amount of time (40%) spent against objective 2B (Figure 57).

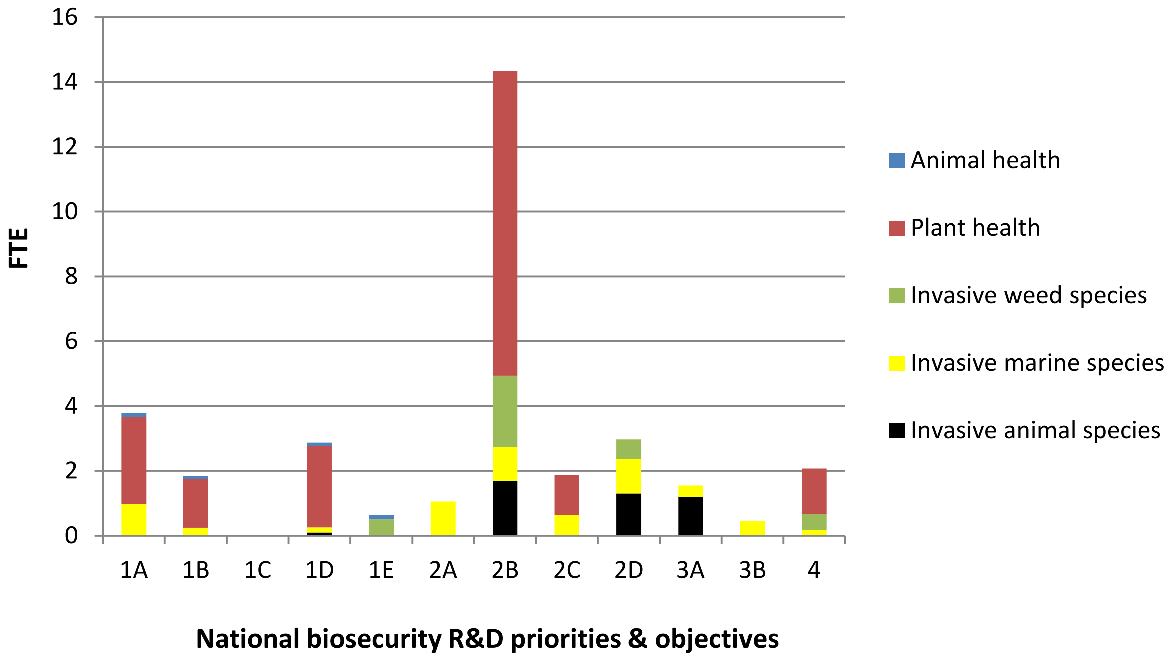

Figure 57. Full time equivalent (FTE) staff in biosecurity R&D by priority/objective by sector

Discipline

FTEs were collected against disciplines (Table 27). For animal health all the FTEs were in the discipline of epidemiology (Table 27). For the plant health sector the greatest FTEs were in the discipline of mycology (31%). For invasive weed species the discipline of ecology and control contained the largest numbers of FTEs (53%; Table 27). For the invasive marine species sector, the majority of FTEs (38%) were in ecology and management and for invasive animal species the greatest FTEs were in the discipline of population ecology (53%; Table 27).

Table 27. Full time equivalent (FTE) staff in biosecurity R&D by discipline

Biosecurity sector	Discipline	FTEs
Animal health	Epidemiology	0.5
Plant health	Mycology	5.8
	Nematology	2.6
	Virology	0.3
	Entomology	5.2
	Soil microbial ecology	1.2
	Disease and pest resistance	2.3
	Quarantine	1.4
Invasive weed species	Bio controllers	0.8
	Spatial ecology	1.0
	Ecology and control	2.0
Invasive marine species	Ecology	2.0
	Modelling	0.1
	Oceanography	0.1
	Ecology and Management	2.4
	Risk Analysis	0.7
	Surveillance	0.5
	Molecular biology	0.5
Invasive animal species	Population ecology	2.3
	Ecology	1.0
	Epidemiology	1.0
Total		**33.4**

4.7.2. Investment

Capability investment through wages

PIRSA spends approximately $2,316,983 per annum on wages for biosecurity R&D capability across the various sectors. Approximately 60% of this amount was invested in wages for the plant health sector, 2% for the animal health sector, 11% for invasive weed species, 15% for invasive marine species and 13% for invasive animal species (Figure 58).

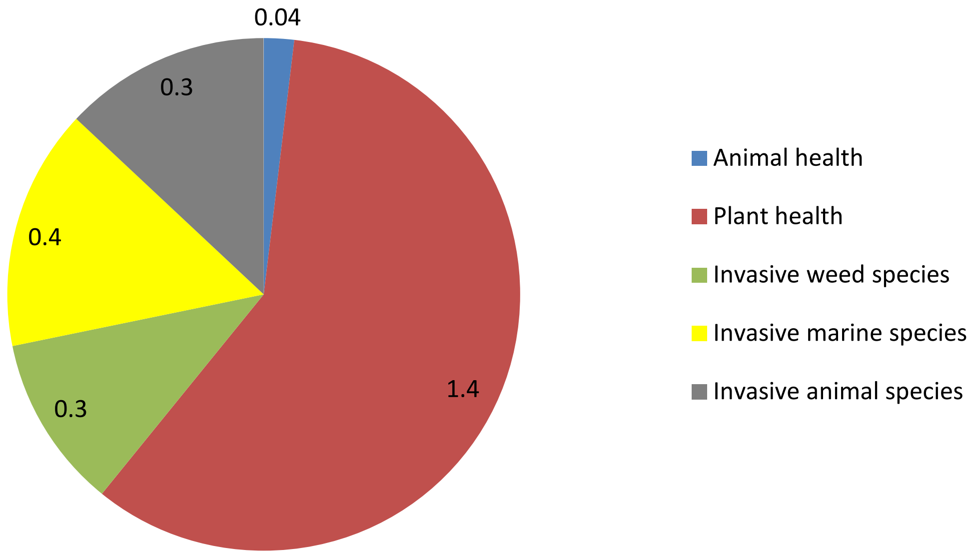

Figure 58. Investment in biosecurity R&D capability through wages (x $1,000,000)

External funding - amounts

The department received external funding in 2011 amounting to $7,826,000. Plant health received the greatest amount of external funding, representing 81% the total amount invested across the sectors (Figure 59). Animal health and invasive animal species received a similar proportion of external funding (4% compared to 6% respectively; Figure 59). Invasive marine species also received external funding amounting to 6% the total amount invested across the sectors and invasive weed species received on 3% (Figure 59).

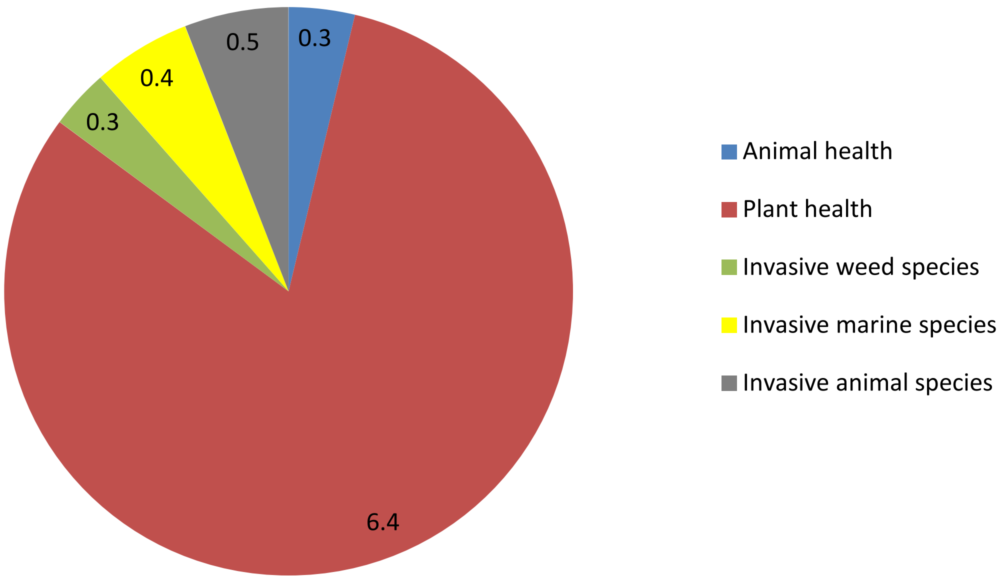

Figure 59. External investment in biosecurity R&D by sector (x $1,000,000)

External funding – sources

Sources of external investment (for 2011) for PIRSA were varied (Table 28). One of the major investors in animal health was the Australian Seafood CRC. For plant health the major investors included GRDC and HAL, and for invasive weed species, external investment was received from SEWPaC and SA Treasury only. The main external investor for invasive animal species was the Invasive Animals CRC and for invasive marine species, the major source of external investment was DAFF.

Table 28. Sources of external investment for Biosecurity R&D in PIRSA

Biosecurity sector	Source of external investment
Animal health	**Australian Government**
	Australian Seafood CRC
	State Government
	PIRSA Fisheries & Aquaculture
	Fisheries Victoria
	RDC funds
	FRDC
	Private Industry
	Clean Seas Tuna Ltd
	Other Industry funding sources
	Fishing Industry Associations
	Miscellaneous
	Ornamental Fish Management Implementation Group
Plant health	**Australian Government**
	CRCNPB
	State Government
	SA
	RDC funds
	GRDC
	GWRDC
	HAL
	SAGIT
Invasive weed species	**Australian Government**
	SEWPaC
	State Government
	Treasury
Invasive animal species	**Australian Government**
	Invasive Animals CRC

	MDBA
	State Government
	City council
	PIRSA Biosecurity
	SA Murray Darling Basin Natural Resource Management (SA MDB NRM) Board
Invasive marine species	**Australian Government**
	DAFF
	State Government
	Premier's Science and Research Fund (PSRF)
	Miscellaneous
	ARCl

External funding – against priority area

External funding by national biosecurity R&D priorities and objectives shows that the major investment across the sectors was against objective 2B (Figure 60). All the sectors were externally funded against this objective, and this objective also received the greatest amount of external funding for the animal health, plant health and invasive weed species sectors (Figure 60). For invasive marine species and invasive animal species, objective 1E received the largest amount of external funding (Figure 60).

Invasive marine species had the greatest external investment coverage across the priority areas and objectives, with only objectives 1C and 3B not externally funded (Figure 60). In contrast invasive weed species only received external funding against objectives 2B and 2D (Figure 60). Animal health received external funding for all objectives except 1B, 1C, 1E, 2A and priority 4 (Figure 60). Plant health received no funding against priority 3, however this sector received external funding against all remaining objectives except 1C, 1E and 2D (Figure 60). Invasive animal species received external funding against all objectives except 1B, 1C, 2D and 3B (Figure 60). This sector did not receive external funding for priority area 4 (Figure 60).

None of the sectors were funded externally for objective 1C (Figure 60). Plant health and invasive marine species were the only sectors which received funding for objective 1B and priority area 4 (Figure 60). Invasive marine species and invasive animal species were the only sectors to receive external funding against objective 1E and animal health was the only sector to receive external investment for objective 3B (Figure 60).

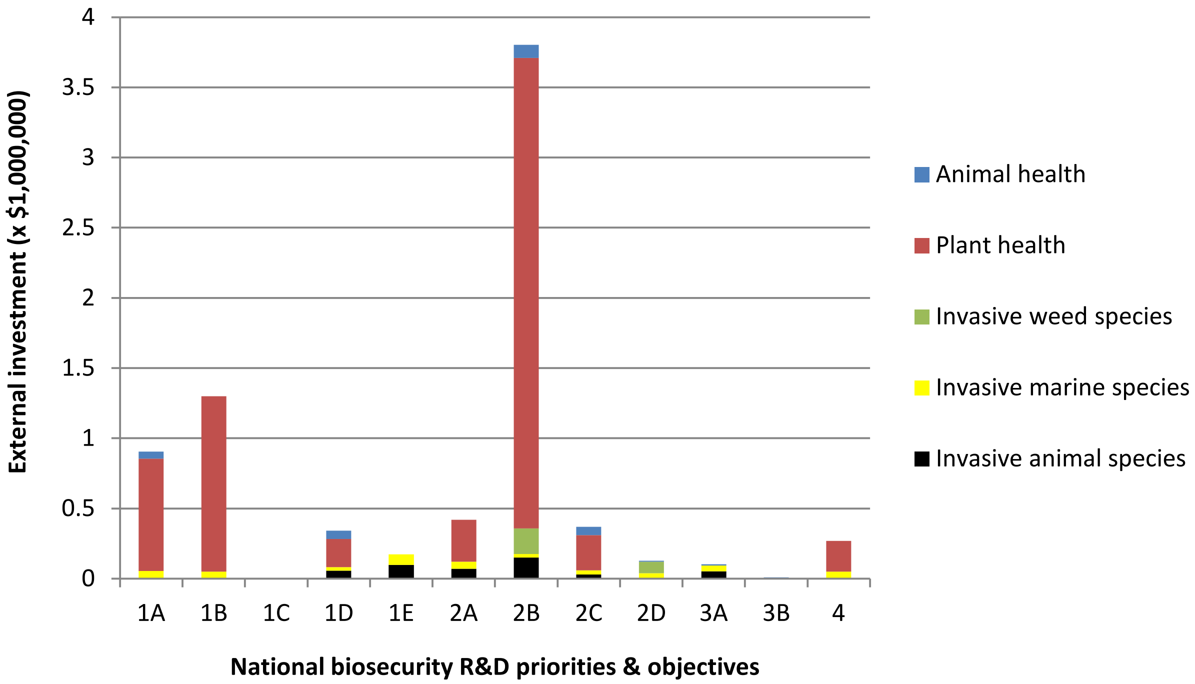

Figure 60. External investment in biosecurity R&D by priority/objective by sector

4.7.3. Infrastructure

Infrastructure investments for PIRSA in the last 5 years (2007 – 2011) included the SA Aquatic Biosecurity Centre at the Roseworthy Campus to a value of $2,600,000 and the Molecular Diagnostics Laboratory at the Waite Campus valued at $1,700,000.

Infrastructure investments forecast for the next 5 years (2012 – 2016) include the SA Aquatic Biosecurity Centre at a cost of $400,000, upgrade to the Quarantine Insectary at the Waite Campus at a cost of $50,000 and upgrade of the Post-Entry Plant Quarantine facility at a cost of $50,000.

Capital expenditure on equipment for the last 2 years (2010 – 2011) that is not captured in infrastructure investments included $150,000 towards a Roche 454 GS Junior next generation DNA sequencer (shared CAPEX purchase) for the Plant Sciences Centre, Waite Campus, various pathology-related equipment for the Waite Campus valued at $200,000, various entomology-related equipment for the Waite Campus valued at $200,000 and rabbit disease molecular testing equipment for Biosecurity SA, Waite Campus valued at $20,000.

The key national biosecurity R&D infrastructure identified by PIRSA includes the Australian Animal Health Laboratories in Geelong, Victoria, the SA Aquatic Biosecurity Centre at the Roseworthy Campus, the Australian Experimental Stockfeed Extrusion Centre at the Roseworthy Campus and the Waite Insect and Nematode Collection at the Waite Campus.

For the SA Aquatic Biosecurity Centre, it is noted that the PC-2 facility is unique in having larger tank capacities than elsewhere so that commercial size fish can be used for experimentation and in being well isolated from natural waters. For the Australian Experimental Stockfeed Extrusion Centre, the extruder and feed mill are ideal for manufacturing livestock, including aquatic animals, and enables diets with therapeutics as a constituent. This facility is unique nationally in that it can make sufficient quantities for meaningful applied trials. It provides ideal integration with University of Adelaide Veterinary School, SARDI and University of Adelaide nutritionists, and SARDI and University of Adelaide feed trialling facilities (aquatic ones at the SA Aquatic Sciences Centre at West Beach) enables vertical integration of RD&E.

4.7.4. Qualitative survey – organisational focus

Separate responses to the questionnaire were provided by Biosecurity SA, SARDI Sustainable Systems and SARDI Aquatic Sciences.

Biosecurity SA

Biosecurity SA provided a response to the questionnaire for the invasive animal species sector.

Future investment in biosecurity R&D by Biosecurity SA is expected to increase in the area of rabbit biological control.

Biosecurity SA's top ten outputs in biosecurity R&D include understanding the epidemiology of rabbit haemorrhagic disease, including genetics of resistance and interactions with conventional control methods used by landholders, the environment and myxomatosis.

Biosecurity SA provides national/international leadership roles in ecology, impacts and management of rabbits, with a particular focus on improving field effectiveness of biological controls and ecology and management of mouse plagues in cereal crops and pest bird management (albeit both at a low level but reflective of limited national expertise in this area). These are also considered to be Biosecurity SA's areas of excellence.

Biosecurity SA has extensive international partnerships in biosecurity R&D. These currently include:

- Instituto Zoloologica Sperimentale, Brescia, Italy
- Liebniz Institute, Berlin, Germany
- CIBIO (Research Center in Biodiversity and Genetic Resources), Porto, Portugal

SARDI Sustainable Systems

SARDI Sustainable Systems provided a response to the questionnaire for the plant health sector.

Future investment in biosecurity R&D is expected to increase in the area of market access, with a decreased focus on horticulture. Future investment in applied entomology and plant disease management is expected to stay the same.

SARDI Sustainable Systems top ten outputs in biosecurity R&D include:

- Development and delivery of quantitative DNA testing for plant pathogens in soil and seed
- Contribution to genetic resistance in cereals and pulses to fungal pathogens and nematodes
- Integrated control strategies for endemic pulse and cereal pathogens
- Elucidation of new disease and pest issues
- Management of complexes of soil-borne pathogens in horticulture
- Integrated control of viticulture pathogens

- Integrated control of snails in broadacre agriculture
- Integrated control of diamondback moth in Brassica
- Development and delivery of new Biological control strategies for horticulture pests e.g. onion thrips
- Contribution to plague locust and fruit fly management

SARDI Sustainable Systems provides national/international leadership roles in applied pathology and entomology- integrated management strategies, molecular diagnostics and soil-borne diseases.

SARDI Sustainable Systems has major international partnerships in biosecurity R&D with New Zealand Plant and Food Research (entomology, pathology), James Hutton Institute (ex Scottish Crop Research Institute) (pathology, molecular diagnostics) and Cornell University (viticultural plant pathology)

SARDI Sustainable Systems identify their areas of excellence to be grains pathology and entomology, molecular diagnostics and soil-borne diseases.

SARDI Aquatic Sciences

SARDI Aquatic Sciences provided a response to the questionnaire for the animal health and invasive marine species sectors.

Future investment in biosecurity R&D is expected to remain similar in the current challenging global environment. The establishment of a national molecular diagnostics centre has been identified as part of the PISC NRPN for Fisheries & Aquaculture Strategy. MISA, primarily in this instance SARDI Aquatic Sciences, is identified as having a “Major” role in marine pests, including invasive species, in the Aquatic Biosecurity, SE, SW and National Hubs. MISA (SARDI along with the Veterinary School, Uni of Adelaide, Flinders University and the SA Museum) is identified as having a “Support” role in Aquatic Animal Health in the above identified Hubs.
SARDI Aquatic Sciences top ten outputs in biosecurity R&D include:

- Molecular tests for diagnostics of environmental samples for pests, including invasive species, and diseases (e.g. a range of DNA probes have been produced for pests, including notifiable invasive species, and diseases)
- Addressing priority aquaculture industry disease and pest issues, in particular parasites of southern bluefin tuna, yellowtail kingfish (YTK), molluscs – abalone and oysters (e.g. submitted Seafood CRC proposal on control of parasites on YTK)
- Addressing priority fisheries industry disease and pest issues (e.g. prawn health survey and presently submitted R&D proposal to FRDC)
- Understanding the basic biology, particularly physiology, of key invasive species (e.g. Caulerpa sp.)
- Understanding the epidemiology of key disease and pest species and their hosts
- Marine port surveys for marine pests
- Developing surveillance tools and capacity, including training, to respond to diseases & pests of environmental significance (e.g. recent intensive FRDC funded training course run in association with the Veterinary School, University of Adelaide)
- Treatment technologies for diseases and pests of marine animals and for treating ballast water

- Developing tools to understand pest and disease risks associated with the importation of aquarium species
- Establishing improved biosecurity facilities for aquatic diseases and pests (e.g. recently opened SA Aquatic Biosecurity Centre)
- Determining and exploiting weaknesses in the biology, ecology and habitat/flow requirements of new and established pest species (i.e. Common carp, *Cyprinus carpio*; Gambusia, *Gambusia holbrooki*; Speckled livebearer, *Phalloceros caudimaculatus*) for the purpose of physical control, removal, exclusion and eradication.
- Developing and proving novel pest fish control/exclusion techniques which have been adopted both nationally and internationally (e.g. native fish friendly carp screens, the carp push trap, the wetland carp separation cage and environmental/habitat manipulation).
- Evaluating the risks, and identifying knowledge gaps associated with the incursion and establishment of new pest species within South Australia's inland waters (i.e. Oriental weatherloach, *Misgurnus anguillicaudatus*; Speckled livebearer, *Phalloceros caudimaculatus*). Including assessment of the risks associated with the ornamental fish industry.

SARDI Aquatic Sciences provides national leadership roles in molecular diagnostics of pests and diseases, and also, environmental effects of treatments of aquatic veterinary medicines and ballast water treatments. Regionally (southern temperate region), they provide leadership roles in some areas of aquatic animal health (e.g. aquacultured southern bluefin tuna, yellowtail kingfish and molluscs). SARDI has developed a strong international collaboration through the Invasive Animals Cooperative Research Centre. This collaboration has resulted in the further development and refinement of technologies developed at SARDI Aquatic sciences (i.e. the carp push trap and the wetland carp separation cage).

SARDI Aquatic Sciences has major international partnerships in biosecurity R&D with:

- Cawthron Institute, NZ
- Kobe University, Japan
- Marine Science & Technology Institute, Mauritius
- Environment Waikato, NZ
- University of Waikato, NZ
- University of Alaska, Fairbanks

SARDI Aquatic Sciences areas of excellence include molecular diagnostics, endemic diseases and pests of endemic hosts and environments, and fish ecology and biology including the application of state-of-art fish tracking and modelling techniques.

4.8. Queensland Government: Department of Agriculture, Fisheries and Forestry

4.8.1. Human Capability

DAFF Qld employs a total of 167.2 FTEs in biosecurity R&D across the biosecurity sectors. All sectors except invasive marine species were represented (Figure 61). Plant health had the largest capability (62%) of the sectors (Figure 61).

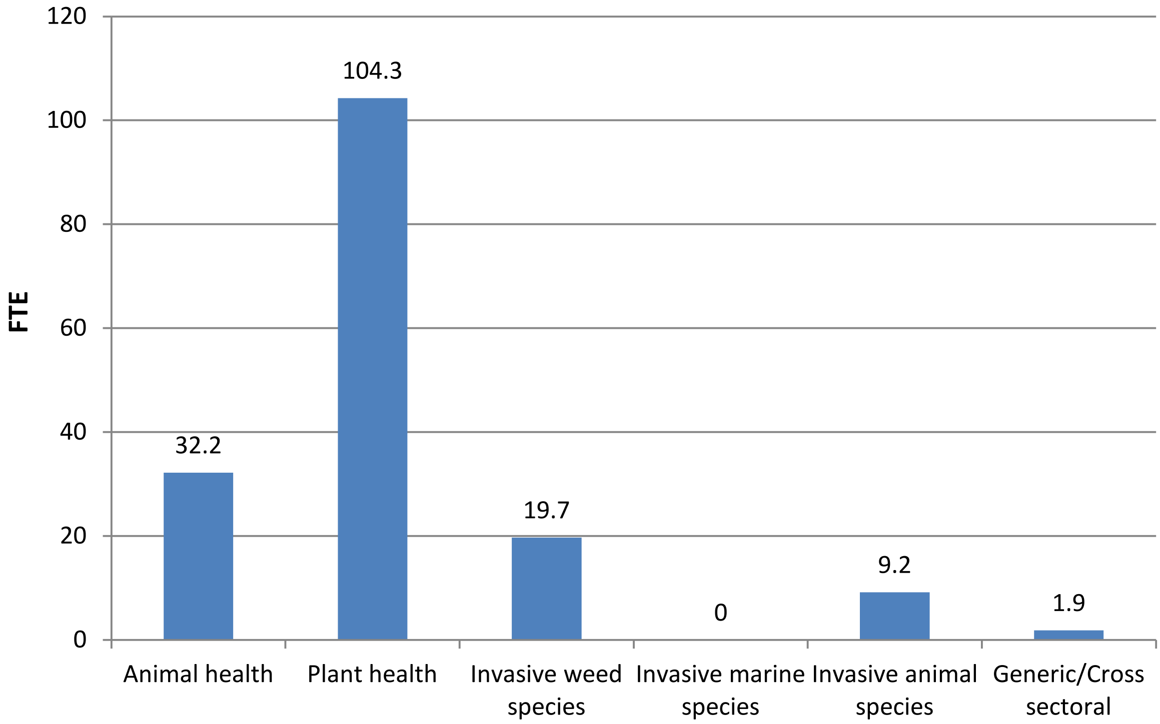

Figure 61. Full time equivalent (FTE) staff in biosecurity R&D by sector

Age

The cumulative age distribution across the biosecurity sectors shows an equal amount of capability (38%) less than 40 years of age and between 40 and 55 years of age (Figure 62). The remaining capability (24%) was over 55 years of age (Figure 62).

The trend was similar for the plant health sector in which there was equal capability aged less than 40 and between 40 and 55 years of age (37% each; Figure 62). The remaining capability (26%) was over 55 years of age (Figure 62).

For animal health the majority of capability (45%) was between 40 and 55 years of age, with the remaining capability spread between those less than 40 (34%) and those over 55 years of age (21%; Figure 62). The invasive animal species sector was similar, with the majority of capability (49%) between 40 and 55 years of age (Figure 62). The remaining capability was spread between those aged less than 40 (40%) and those over 55 years of age (11%; Figure 62).

For invasive weed species the majority of capability (51%) was less than 40 years of age, with the remaining capability spread between the 40 - 55 (29%) and >55 (20%) age brackets (Figure 62).

The majority of capability in the generic/cross sectoral group (46%) was between 40 and 55 years of age, with the remaining capability spread equally between those aged less than 40 and those over 55 years of age (Figure 62).

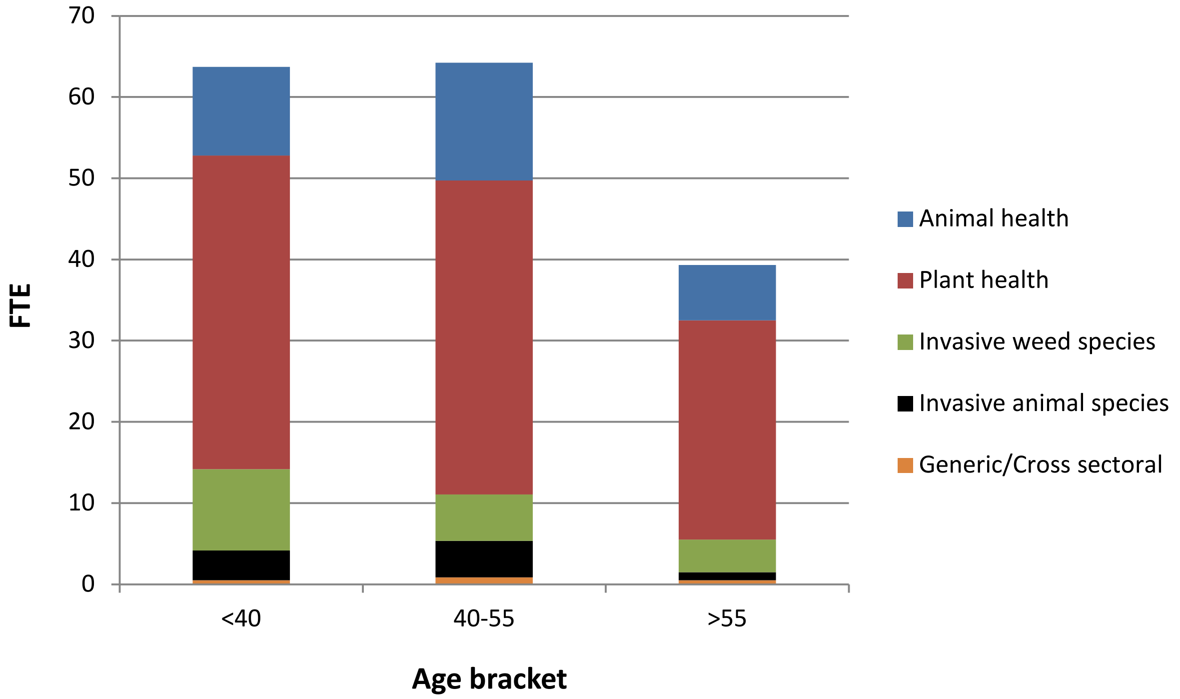

Figure 62. Full time equivalent (FTE) staff in biosecurity R&D by age bracket by sector

Research role

The predominant role in biosecurity R&D in DAFF Qld was researcher, accounting for 54% of research effort, with the majority of remaining effort (45%) provided by technical support (Figure 63). Only 0.1% of capability was provided by postgraduates, and 1% by postdoctoral researchers (Figure 63). Furthermore, all this capability was in the plant health sector (Figure 63).

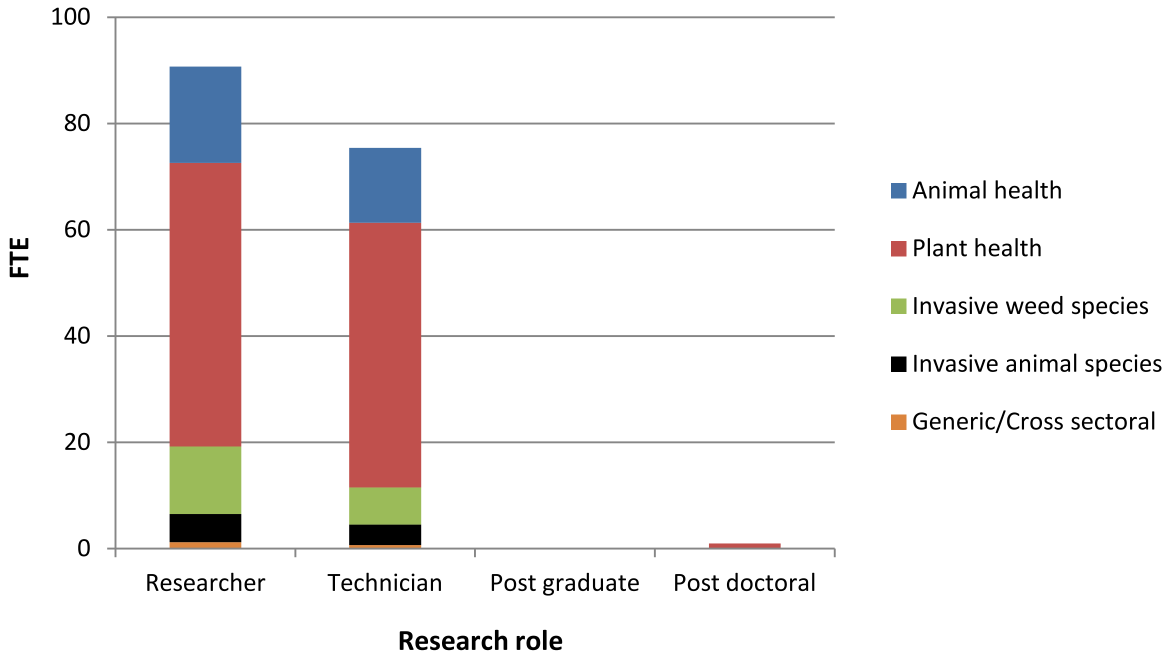

Figure 63. Full time equivalent (FTE) staff in biosecurity R&D by research role by sector

Capability against priority area

FTEs were collected against the national biosecurity priority areas. The data shows DAFF Qld spends over 95% of effort against priorities 1 and 2, with approximately 60% of that effort invested in objective 2B (Figure 64). All sectors conducted R&D against these two priorities except for generic/cross-sectoral R&D (Figure 64). The only priorities/objectives in which all sectors were conducting R&D were objective 2A and priority 4, although for some sectors the FTEs spent on these areas were very low (Figure 64).

Priority area 1 accounted for 31% the total research effort across all the priorities (Figure 64). Within this priority area, the majority of research effort (42%) was against objective 1B and all sectors except invasive weed species and invasive animal species conducted R&D against this objective (Figure 64).

Priority area 2 accounted for 65% the total research effort across all the priorities (Figure 64). Within this priority area, the greatest research effort was against objective 2B (52%). All sectors conducted R&D against objective 2A which accounted for 26% of the research effort against priority 2 (Figure 64). Plant health, invasive weed species and generic/cross-sectoral R&D was all conducted against objective 2C which accounted for only 8% the research effort against priority 2 (Figure 64). Thirteen percent of R&D was against objective 2D and all sectors except generic/cross-sectoral conducted R&D against this objective (Figure 64).

Only 2% of the total research effort was against priority area 3 (Figure 64). This effort was all against objective 3A and only conducted by the invasive weed species and invasive animal species sectors (Figure 64).

All sectors conducted R&D against priority 4, however this accounted for only 2% the total research effort across all the priorities (Figure 64).

Looking at the sectors individually, animal health conducted biosecurity R&D across all the priority areas except 3, and all objectives within priorities 1 and 2 except 1C, 1D and 2C (Figure 64). The majority of R&D (53%) was against objective 2A (Figure 64).

Plant health conducted R&D against all the priorities except for 3, and all objectives within priorities 1 and 2 except for 1C (Figure 64). The greatest amount of time (36%) was spent against objective 2B (Figure 64).

Invasive weed species R&D was conducted across all the priorities except 1 and all objectives within priorities 2 and 3 except 3B (Figure 64). The majority of time was spent against objective 2B (73%; Figure 64).

Invasive animal species conducted R&D against all priorities and all objectives except 1A, 1C, 1E, 2C and 3B (Figure 64). The greatest percentage of time (37%) was spent against 2B (Figure 64).

R&D in the generic/cross-sectoral group was conducted against all priorities except 3 and all objectives within priorities 1 and 2 except 1C, 2B, 2D (Figure 64). The majority of FTEs for this sector (57%) were against objective 1D (Figure 64).

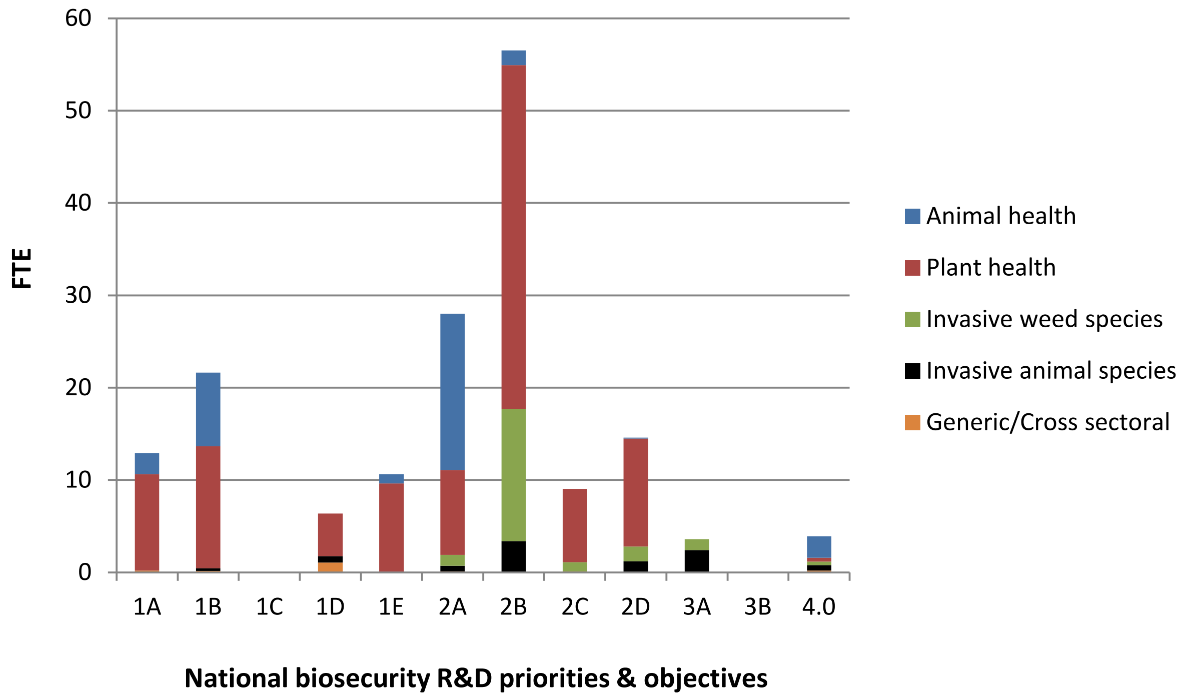

Figure 64. Full time equivalent (FTE) staff in biosecurity R&D by priority/objective by sector

Discipline

FTEs were collected against disciplines (Table 29). For animal health the greatest percentage of FTEs (26%) was in the discipline of epidemiology (Table 29). For the plant health sector the greatest capabilities were in the disciplines entomology (45%) and plant pathology (22%; Table 29). For invasive weed species the disciplines of agronomy and population ecology contained the greatest percentage of FTEs (58%). For the invasive animal species sector, the majority of FTEs (57%) were in the discipline of ecology and for generic/cross-sectoral R&D, the greatest percentage of FTEs (73%) were in the discipline of toxicology (Table 29).

Table 29. Full time equivalent (FTE) staff in biosecurity R&D by discipline

Biosecurity sector	Discipline	FTEs
Animal health	Anatomical pathology	0.8
	Bacteriology	3.2
	Biochemistry	1.2
	Clinical Pathology	4.5
	Entomology/Parasitology	0.5
	Epidemiology	8.3
	Field/WHS	0.5
	Histology	0.9
	Information management	0.1
	Media/Kitchen	0.1
	Molecular Biology	1.3
	Mycology	0.3
	Parasitology	3.6
	Protozoology	0.2
	Serology	2.9
	Veterinarian	0.1
	Virology	3.9
Plant health	Bacteriology	1.3
	Disease & pest resistance	6.0
	Entomology	46.7
	IT and information management	1.0
	Modelling	1.0
	Molecular biology	1.0
	Mycology	8.5
	Nematology	9.0
	Plant Pathology	23.0
	Soil microbial ecology	2.7
	Virology	4.2
Invasive weed species	Agronomy	0.2
	Agronomy and population ecology	11.5
	Biological Control and entomology	1.0
	Weed sciences	7.0

Invasive animal species	Ecology	5.2
	Population ecology and control	2.0
	Toxicology	2.0
Generic/Cross sectoral	Risk analysis	0.5
	Toxicology	1.4
Total		**167.2**

4.8.2. Investment

Capability investment through wages

DAFF Qld spends approximately $12,924,866 per annum on wages for biosecurity R&D capability across the various sectors. Approximately 64% of this amount was invested in wages for the plant health sector, 19% for the animal health sector, 11% for invasive weed species, 6% for invasive animal species and only 1% for generic/cross-sectoral R&D (Figure 65).

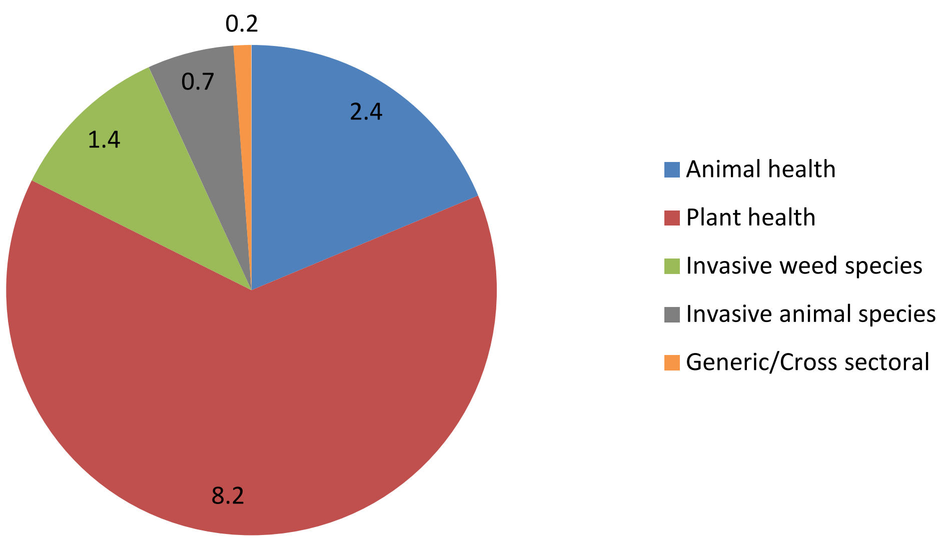

Figure 65. Investment in biosecurity R&D capability through wages (x $1,000,000)

External funding

The department received external funding in 2011 amounting to $28,236,277. The majority of this external investment was directed to the animal health and plant health sectors (Table 30). Some of the major investors included the Australian and state governments (fire ant funds), GRDC, HAL, ACIAR and the CRCNPB (Table 30).

Table 30. Sources of external investment for Biosecurity R&D in DAFF Qld

Australian Government
ABRS
ACIAR
CSIRO
DAFF
DEWHA
Fire Ants
State Government
Brisbane City Council
Department of Agriculture and Food, Western Australia
DPI Vic
Fire Ants - States
DPI NSW
PIRSA
RDC funds
BSES
Cotton Research and Development Corporation
GRDC
HAL
MLA
RIRDC
Other Industry funding sources
Australian Sweetpotato Growers Association
Bundaberg Fruit and Vegetable Growers Co-Operative Limited
Peanut Company of Australia
Plantation Growers
Commercial funds
Fitzroy Basin Association Incorporated
Other sources
Sunshine Horticultural Services
The Northern Gulf Resource Management Group
Miscellaneous - Overseas Business
CIMMYT
Miscellaneous - Universities
Queensland Alliance for Agriculture and Food Innovation
University of Queensland

University of Southern Queensland
University of Tasmania
University of Western Australia
Miscellaneous - CRC's
Australian Biosecurity CRC for Emerging Infectious Diseases
Cotton Catchment Communities CRC
CRCNPB
Invasive Animals CRC

External funding against national biosecurity R&D priorities and objectives shows that all of the priority areas and objectives were funded except objective 1C (Figure 66). The greatest investment across the sectors was in objectives 1D and 2B, with 51% of total external funding against objective 1D and 27% against 2B (Figure 66). Priorities 3 and 4 received the smallest amount of external funding (Figure 66).

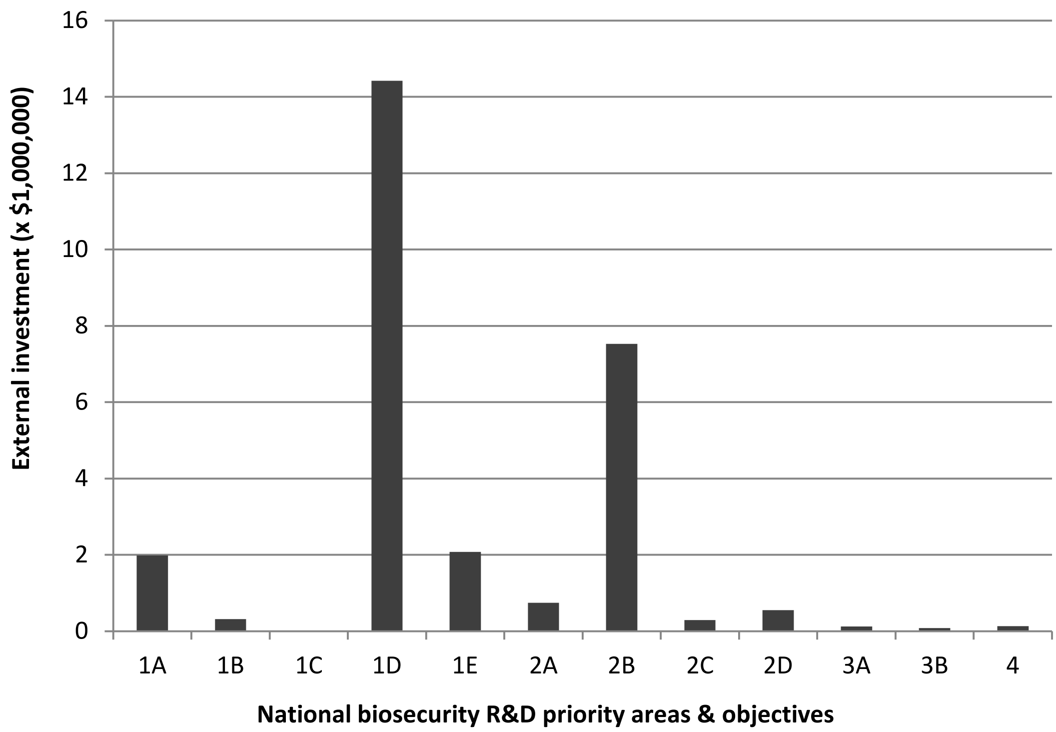

Figure 66. External investment in biosecurity R&D by priority/objective

4.8.3. Infrastructure

Infrastructure investments for DAFF Qld in the last 5 years (2007 – 2011) included the EcoSciences Precinct[27] in Dutton Park, Brisbane at a cost of $259,500,000, Health and Food

[27] Note that this infrastructure was a joint venture between the Queensland Government and CSIRO and is not solely utilised for biosecurity R&D purposes

Sciences Precinct[28] at Coopers Plains, Brisbane at a cost of $101,300,000, Robert Wicks Pest Animal Research Station at Inglewood valued at $900,000 and LIMS valued at $1,300,000.

Infrastructure investments forecast for the next 5 years (2012 – 2016) include the Tropical Biosecurity Laboratory[29] at Townsville at a cost of $17,000,000 and the Robert Wicks Pest Animal Research Station at Inglewood at a cost of $180,000.

The key national biosecurity R&D infrastructure identified by DAFF Qld includes the Robert Wicks Pest Animal Research Station at Inglewood valued at $2,200,000.

4.8.4. Qualitative survey – organisational focus

DAFF Qld provided one response to the questionnaire covering animal health, plant health, invasive weed species and invasive animal species.

Future investment in biosecurity R&D is expected to increase in the following areas:

- Emerging infectious diseases
- Biosecurity Intelligence
- Plant disease diagnostics
- Social factors affecting control and eradication of invasive pests and diseases
- Development and validation of new molecular based diagnostic tests and technology for use in disease investigation and detection of invasive animal, plant and aquatic species
- Methodologies for deriving intelligence information from field and laboratory derived data
- Methodologies for the detection new and emerging diseases
- Tropical aquatic animal health and diagnostics

Future investment in biosecurity R&D is expected to decrease in the following areas:

- Methods to control and eradicate weeds
- Development of diagnostic tests for the detection of endemic diseases

Future investment in biosecurity R&D is expected to stay the same in the following areas:

- Animal Health diagnostic test development for exotic diseases
- Toxicology

DAFF Qld’s top ten outputs in biosecurity R&D include:

- Controlling weeds
- Controlling pest animals
- Understanding the genetics of invasive species
- Disease spread modelling
- Plant health diagnostics
- Understanding emerging infectious diseases especially those from wildlife
- Understanding tropical aquatic animal diseases
- Methods of remote surveillance and sensing of invasive species

[28] Note that this infrastructure was a joint venture between the Queensland Government and CSIRO and is not solely utilised for biosecurity R&D purposes

[29] Development of this facility has been scrapped

- New methods of detecting disease causing agents
- Plant toxicology

DAFF Qld provides national/international leadership roles in remote sensing of invasive species, some areas of disease investigation in animals, control of invasive plant species and genetic diversity of invasive animal species.

DAFF Qld has extensive international partnerships in biosecurity R&D with FAO, Pfizer, United States Department of Agriculture (USDA), University of Taiwan and the Chinese Academy of Science.

DAFF Qld identified their areas of excellence as:

- Animal Health Diagnostics
- Invasive species control and eradication especially biological control systems
- Plant health diagnostics
- Control of the spread of invasive plant species
- Tropical aquatic species health and diagnostics

4.9. Northern Territory Government: Department of Resources – Primary Industry, Fisheries and Resources

4.9.1. Human Capability

DoR employs a total of 7.7 FTEs in biosecurity R&D across the biosecurity sectors of plant health, animal health and also generic/cross-sectoral R&D. The majority of capability was in the animal health (52%) and plant health (45%) sectors (Figure 67).

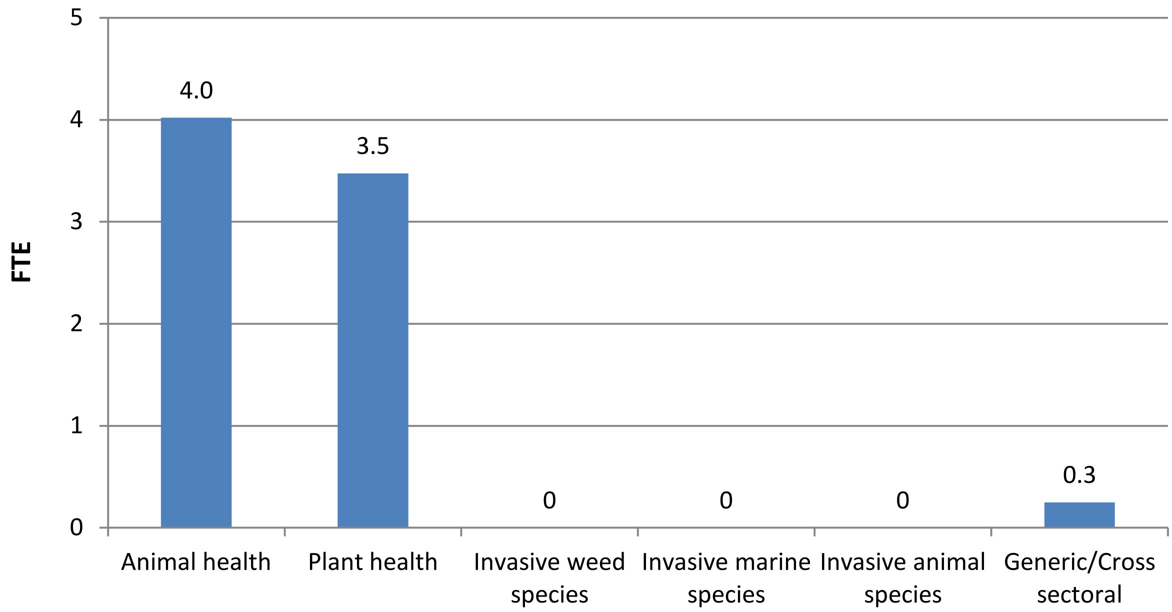

Figure 67. Full time equivalent (FTE) staff in biosecurity R&D by sector

Age

The cumulative age distribution across the biosecurity sectors shows that the majority of capability (42%) was between 40 and 55 years of age (Figure 68). Most of this capability (92%) was in the animal health sector (Figure 68). The remaining capability for animal health was evenly spread between those aged less than 40 and those over 55 years of age (Figure 68).

The majority of capability in the plant health sector (53%) was over 55 years of age (Figure 68). Only 7% of capability was between 40 and 55 years of age, compared to 40% that were less than 40 years of age (Figure 68).

All the capability in generic/cross-sectoral R&D was less than 40 years of age (Figure 68).

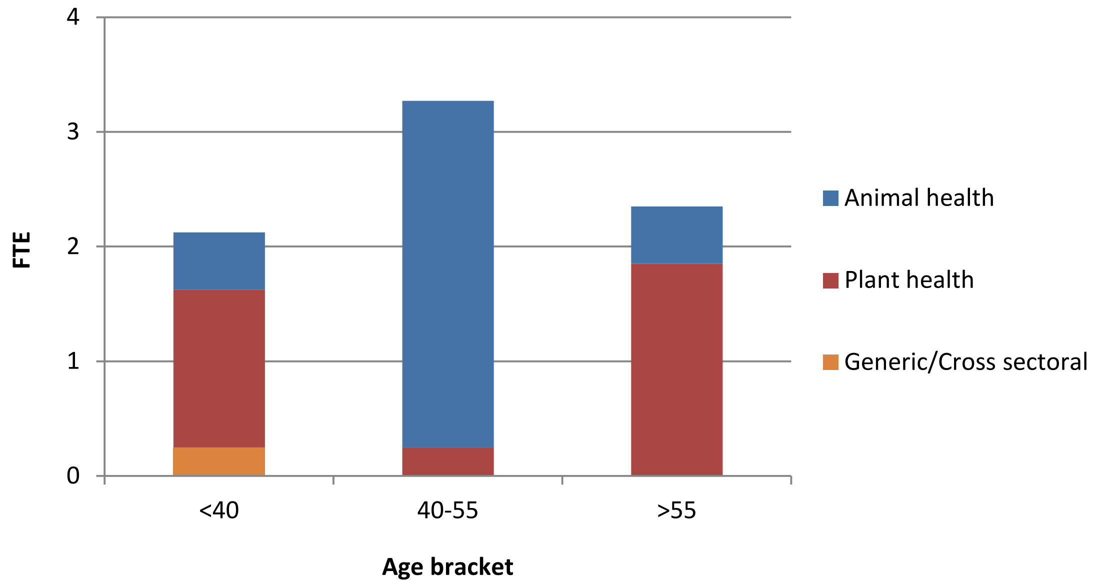

Figure 68. Full time equivalent (FTE) staff in biosecurity R&D by age bracket by sector

Research role

The predominant role in biosecurity R&D in DoR was researcher, accounting for 71% of the total research effort (Figure 69). This researcher capability was spread between the sectors of animal health (58%), plant health (37%) and the generic/cross sectoral group (5%). All the remaining research effort was provided by technicians; however this technical support existed only for the animal health and plant health sectors (Figure 69). No capability was provided by postgraduates or postdoctoral researchers (Figure 69).

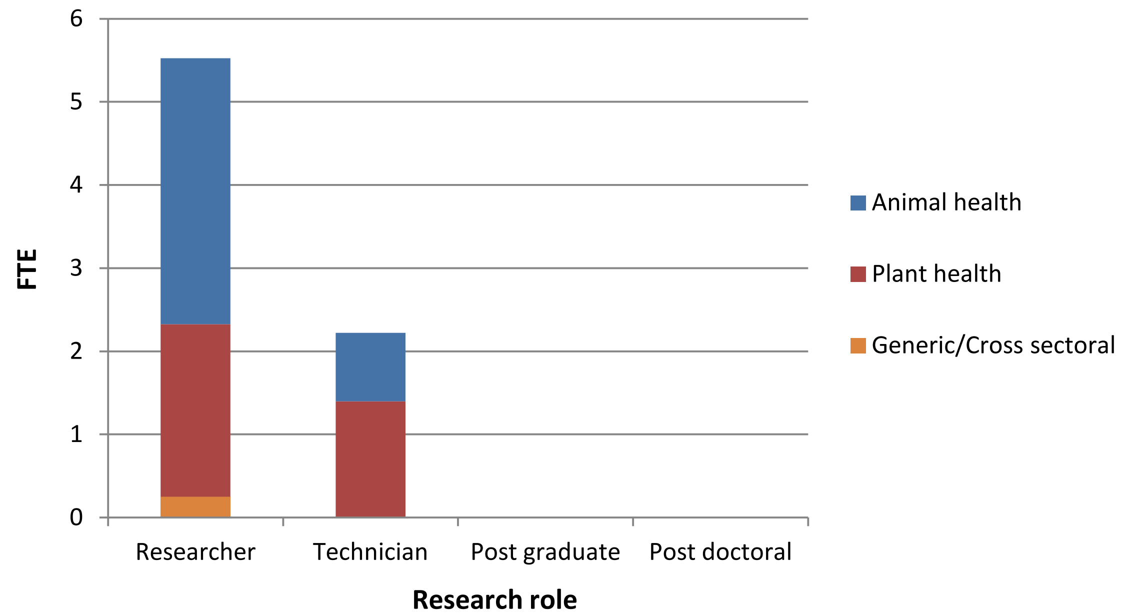

Figure 69. Full time equivalent (FTE) staff in biosecurity R&D by research role by sector

Capability against priority area

FTEs were collected against the national biosecurity priority areas (Figure 70). Results show DoR spent the majority of R&D effort (69%) against priority 1, with approximately 34% of that effort invested in objective 1A, 32% of effort invested in objective 1B and the remaining research effort (3%) invested in objective 1D (Figure 70). The animal health, plant health and generic sectors all conducted R&D against this priority (Figure 70). In contrast, no R&D was conducted against objectives 1C, 1E or 2C (Figure 70).

All the R&D in the animal health sector was against priority 1, with the majority of time spent against objectives 1A (50%) and 1B (48%; Figure 70). The remaining research effort (2%) was against objective 1D (Figure 70).

The plant health sector conducted R&D against all four priority areas, with the greatest amount of effort invested in objective 2B (60%; Figure 70). No R&D was conducted against objectives 1C, 1E or 2C (Figure 70).

All the generic/cross-sectoral R&D was conducted against objective 1B (Figure 70).

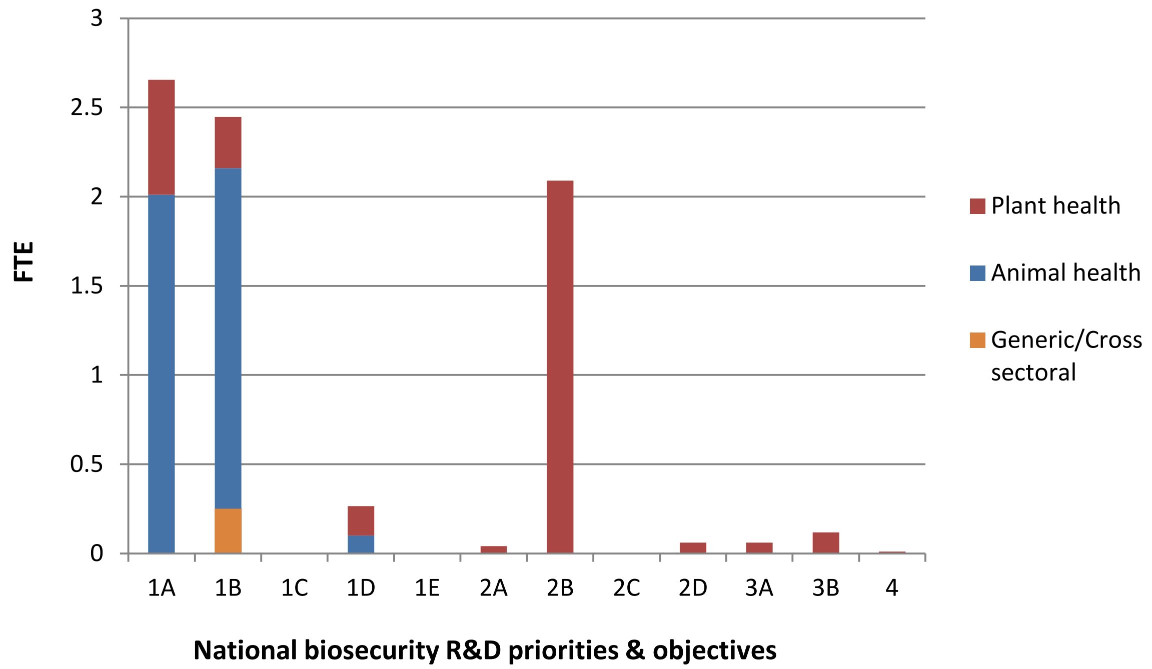

Figure 70. Full time equivalent (FTE) staff in biosecurity R&D by priority/objective by sector

Discipline

FTEs were collected against disciplines (Table 31). For the animal health sector, 39% of capability was in the discipline of virology, 37% in anatomical pathology and 24% in the discipline of bacteriology (Table 31). For plant health, 64% of capability was in the discipline of entomology, 32% in pathology, 2% in bioinformatics and 2% in molecular biology (Table 31). For generic/cross-sectoral R&D, the capability was equally spread between the disciplines of bioinformatics and molecular biology (Table 31).

Table 31. Full time equivalent (FTE) staff in biosecurity R&D by discipline

Biosecurity sector	Discipline	FTEs
Animal health	Anatomical pathology	1.5
	Bacteriology	1.0
	Virology	1.6
Plant health	Bioinformatics	0.1
	Entomology	2.2
	Molecular biology	0.1
	Pathology	1.1
Generic/Cross sectoral	Bioinformatics	0.1
	Molecular biology	0.1
Total		**7.7**

4.9.2. Investment

Capability investment through wages

DoR spends approximately $628,010 per annum on wages for biosecurity R&D capability across the various sectors. Approximately 54% of this amount was invested in wages for the animal health sector, 43% for the plant health sector and 3% for generic/cross-sectoral R&D (Figure 71).

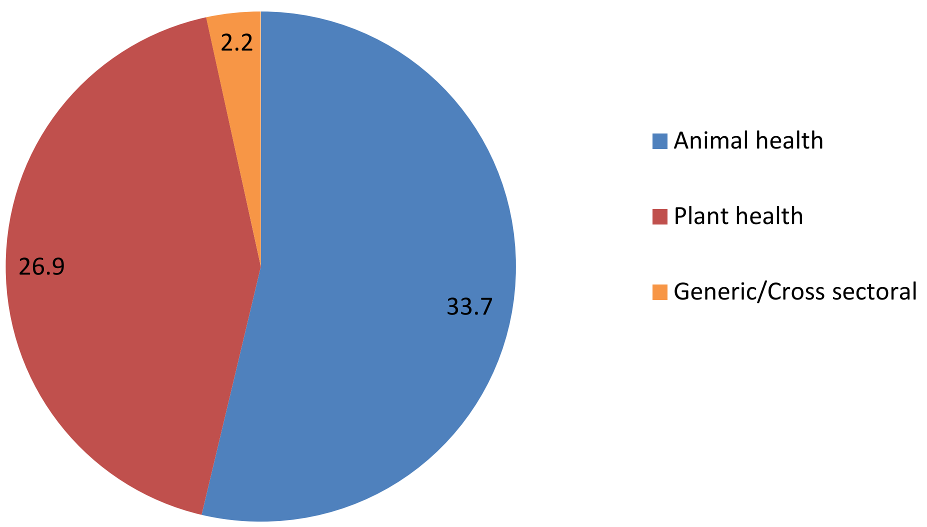

Figure 71. Investment in biosecurity R&D capability through wages (x $10,000)

External funding – amounts and sources

The majority of funding for biosecurity R&D provided to NT Departments was from the Australian Government and RDCs with an increasing proportion of plant biosecurity R&D being gained for offshore activities (Table 32). In 2011 the Department of Land Resource Management (DLRM) was involved in externally funded projects totalling approximately $2,700,000. It should be noted that the majority of this funding went to the NERP – Northern Hub ($1,300,000), with whom DLRM has research partnership agreements. Research funding to DLRM, was a small part of this total funding; at the time of calculation it will total approximately $340,000 between 2011-14. Funding was obtained from RIRDC, DEWHA-NERP, TNRM and MLA (Table 32). Additional external funding has been received for weed management, some of which may be linked to biosecurity and the scope of this project. Due to the date comments were sort, a full listing/calculation of these funds was not possible.

Table 32. Sources of external investment for Biosecurity R&D in NT DoR or Department of Natural Resources, Environment, the Arts and Sport (DNRETAS)

Biosecurity sector	Source of external investment
Animal health	**Australian Government**
	DAFF
	RDC funds
	MLA
	RIRDC
	Private Industry
	Pfizer
Plant health	**Australian Government**
	ACIAR
	DAFF
	RDC funds
	HAL
	RIRDC
	Private Industry
	Agrochemical firms
Invasive weed species	**Australian Government**
	DEWHA-NERP
	Territory Government
	TNRM
	RDC funds
	MLA
	RIRDC

External funding – against priority areas

Animal biosecurity R&D was mainly against priority/objective 1B for example to conduct surveillance for bluetongue disease and the detection of new serotypes that might enter northern Australia or 2B developing approaches to manage established pests and diseases such as viruses affecting crocodiles. Plant biosecurity R&D was funded was funded for wider range of projects ranging for development of knowledge base for new pests of diseases (priority/objective 1A), development of national protocols for detection of exotic diseases (1B) to developing effective approaches to managing established pests or diseases such as termites (2B).

4.9.3. Infrastructure

Infrastructure investments for DoR for the last 5 years (2007 – 2011) included a PCR clean room valued at $104,000, UPS power points valued at $4,000 and BMS computer upgrade at a cost of $24,000.

Infrastructure investments for DoR forecast for the next 5 years (2012 – 2016) include a QC3 room upgrade valued at $500,000.

Capital expenditure on equipment in the last two years (2010 – 2011) that is not captured in infrastructure investments included a PCR realtime machine valued at $35,000 and a -70^{o}C freezer valued at $18,000.

4.9.4. Qualitative survey – organisational focus

DoR provided separate responses to the questionnaire for the animal health and plant health sectors.

Animal health

Future increase in investment in animal health is subject to gaining industry or other sources of funding, to use in conjunction with internal DoR funding. The organisation's top ten outputs in biosecurity R&D for animal health include R&D on arboviruses, in particular blue tongue (all aspects), bovine ephemeral fever (serotypes and pathogenesis), crocodile virology, parasitology and immunology, enhanced diagnostics, fish pathology and wildlife pathology.

DoR takes national and international leadership roles through the Berrimah Veterinary Laboratory (BVL) and its staff, which have national and international recognition for arbovirus R&D and are ideally placed to conduct this area of research with Australia's most valuable collection of endemic isolates and associated sera. In addition, BVL and its staff are rapidly gaining a national reputation for the excellence and innovation of its crocodile research and diagnostics which have been recognised by the crocodile industry, funding agencies (e.g. RIRDC) and interstate collaborators.

International partnerships with DoR fluctuate according to funding and BVL has on occasion been effectively blocked by other organisations/agencies from establishing international links. Over the last 5-10 years the most significant collaboration has been with Maleman School of Health Research, New York, USA, Pulbright, UK and Pfizer.

DoR identified their areas of excellence as arboviruses, in particular blue tongue and crocodile pathology.

Plant health

Future investment in plant health by DoR is expected to increase.

The organisation's top ten outputs in biosecurity R&D for plant health include R&D on target pests (termites, mango malformation, banana fusarium wilt, fruit flies, mango fruit borer, red-banded mango caterpillar and cocoa pod borer) and R&D skills including molecular diagnostics (pathogens and insects), tropical plant pests and diseases (frequent overseas work), pheromones, and termites. These are also considered to be the key areas of excellence for DoR plant health.

DoR takes national and international leadership roles through R&D in the areas of insect DNA barcoding, termites and phytoplasmas.

DoR has international partnerships with Government agricultural departments in Timor Leste, Indonesia, Cambodia, Solomon Islands, and Philippines (mainly through ACIAR or DAFF projects).

4.10. Western Australian Government: Department of Agriculture and Food

4.10.1. Human Capability

Department of Agriculture and Food, Western Australia (DAFWA) employs a total of 39.3 FTEs in biosecurity research and development (R&D) across the sectors of animal health, plant health, and invasive animal species (Figure 72). The majority of FTEs are in the plant health sector (54%).

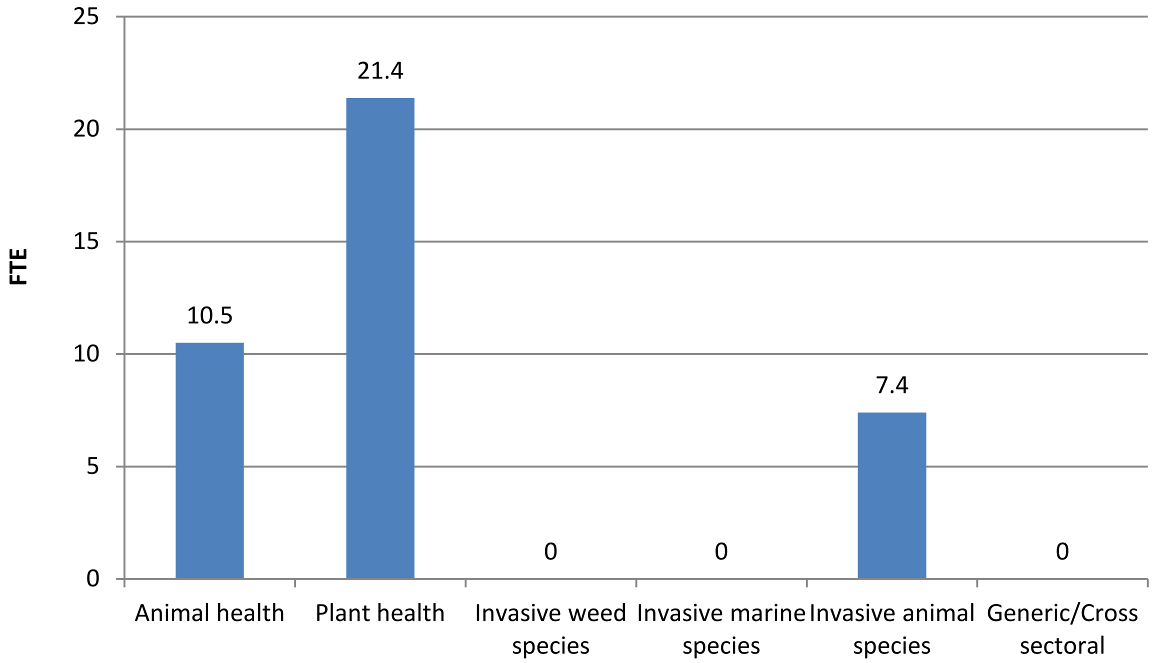

Figure 72. Full time equivalent (FTE) staff in biosecurity R&D by sector

Age

The age distribution across the biosecurity sectors shows that approximately half the capability (51%) was between 40 and 55 years of age (Figure 73). The remaining capability was fairly evenly spread between staff less than 40 years of age (22%) and staff over 55 years of age (27%; Figure 73).

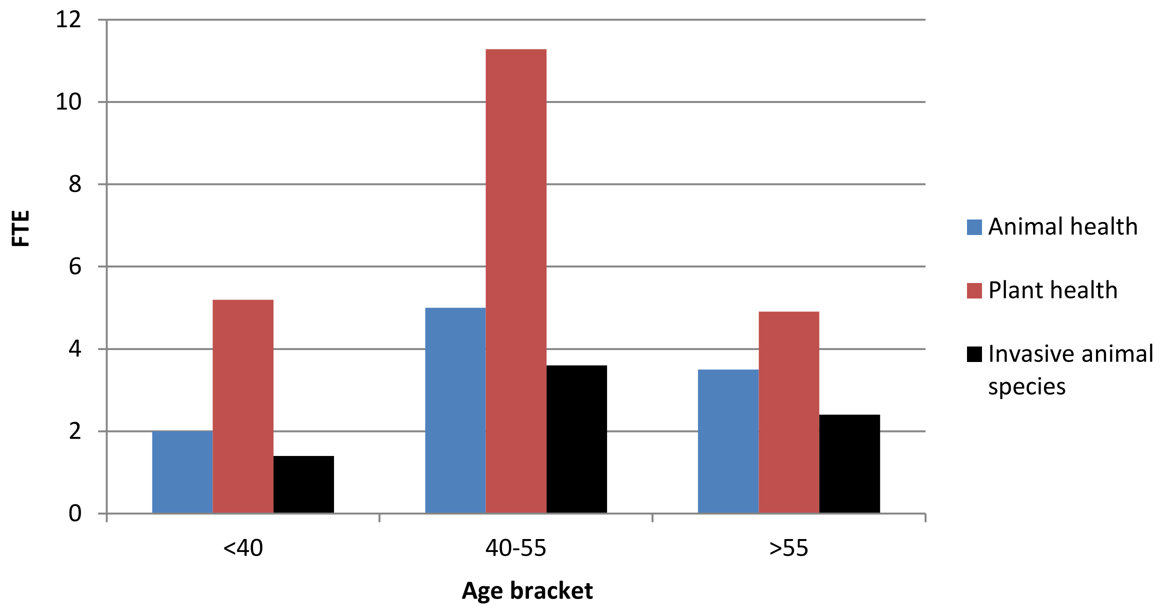

Figure 73. Full time equivalent (FTE) staff in biosecurity R&D by age bracket

Research role

The predominant research role in biosecurity R&D was technician, accounting for 50% of research effort (Figure 74). The majority of remaining effort was provided by researchers (49%) and postgraduates (1%), although the postgraduate capability was only in the plant health sector (Figure 74).

For the animal health sector there was a higher ratio of researchers to technicians (Figure 74). The trend was opposite for the plant health and invasive animal species sectors in which there was a higher ratio of technicians to researchers (Figure 74).

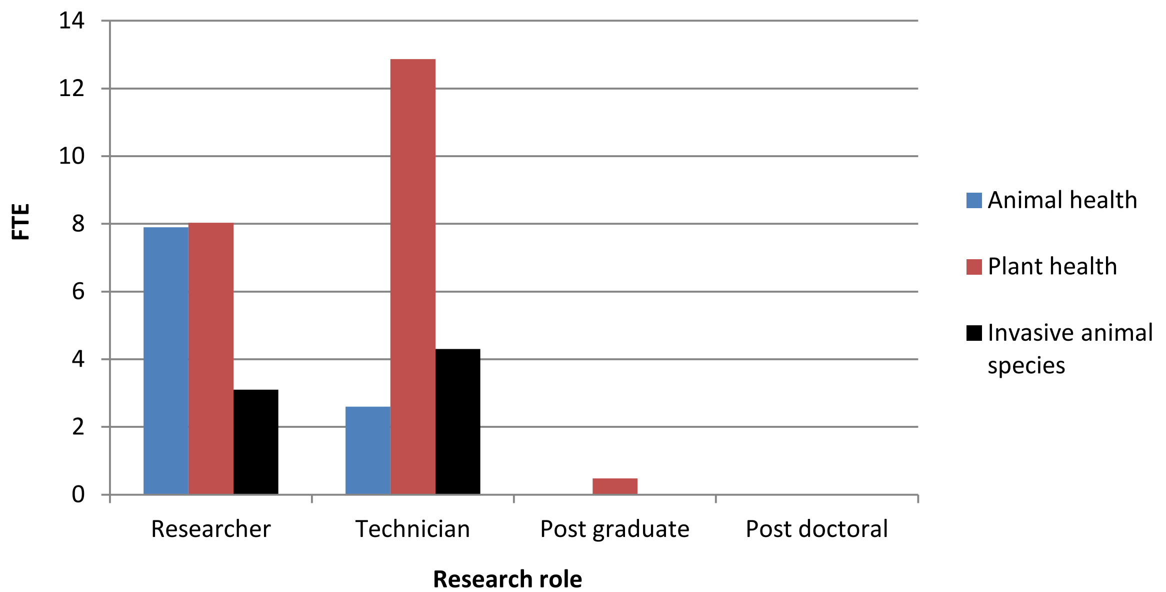

Figure 74. Full time equivalent (FTE) staff in biosecurity R&D by research role

Capability against priority area

DAFWA spent the majority (59%) of R&D effort against priority 1 (Figure 75). Within priority area 1, the greatest amount of effort was against objectives 1A (35%) and 1E (23%; Figure 75). All sectors conducted R&D against objectives 1A and 1E, however only animal health and plant health conducted R&D against objectives 1B, 1C and 1D (Figure 75).

A total of 26% of FTEs were against priority 2 (Figure 75). Within priority area 2 the majority of time (35%) was spent against objective 2C (Figure 75). All sectors conducted R&D against priority area 2 and the objectives within, except objective 2D for which only the plant health sector conducted R&D (Figure 75).

Priority 3 accounted for 9% of total R&D effort, and this effort was spread fairly evenly between objectives 3A and 3B (Figure 75). The plant health and invasive animal species sectors conducted R&D against this priority area, however the animal health sector did not (Figure 75).

Priority 4 accounted for only 6% the total R&D effort. Animal health, plant health and invasive animal species all conducted R&D against this priority area (Figure 75).

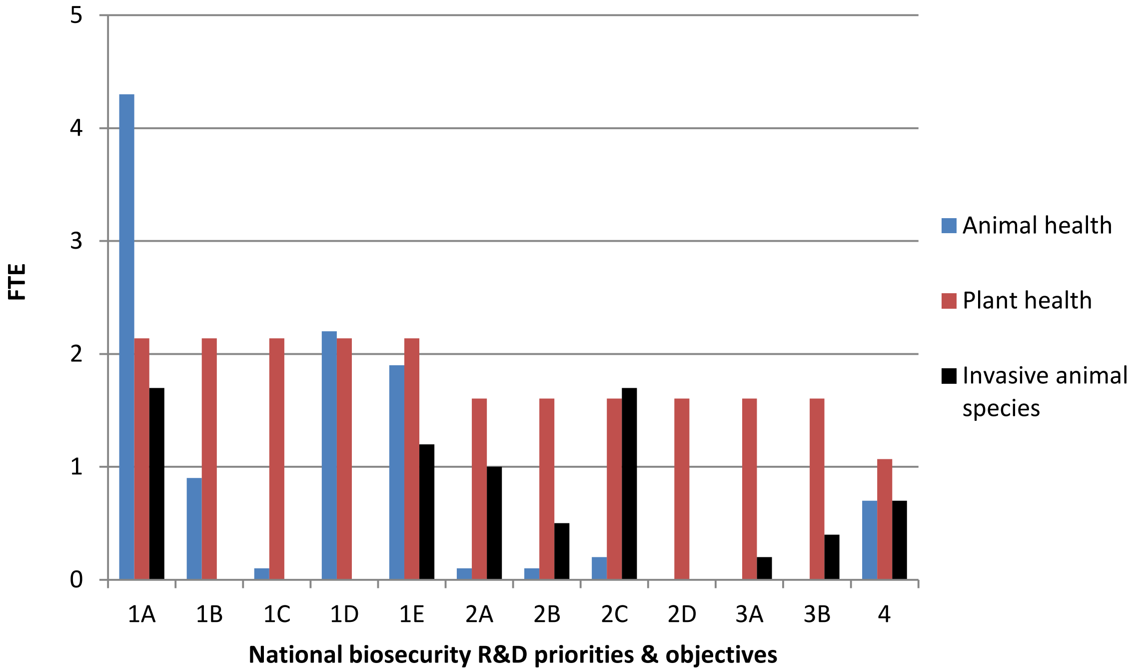

Figure 75. Full time equivalent (FTE) staff in biosecurity R&D by priorities and objectives

Discipline

FTEs were collected against disciplines (Table 33). For animal health, the greatest capability was in laboratory support, accounting for 28% of animal health FTEs (Table 33). Clinical pathology and epidemiology also accounted for a large percentage of the capability, with 22% and 21% of FTEs respectively (Table 33). Virology contained the lowest capability (3%).

For the plant health sector, pathology (27%) and pest management (17%) had the greatest capability (Table 33). The lowest capabilities were in biological control, advisory and quarantine and pest resistance, which each accounted for only 1% of FTEs (Table 33).

For invasive animal species, 62% of capability was in the discipline of population ecology, 24% in spatial ecology and the remaining 14% in communications (Table 33).

Table 33. Full time equivalent (FTE) staff in biosecurity R&D by discipline

Biosecurity sector	Discipline	FTEs
Animal health	Bacteriology	0.5
	Clinical pathology	2.3
	Epidemiology	2.2
	Laboratory support	2.9
	Parasitology	1.1
	Toxicology	1.2
	Virology	0.3
Plant health	Advisory	0.2
	Biological control	0.2
	Diagnostics	2.2
	Entomology	1.3
	Eradication	1.0
	Horticulture	1.1
	Nematology	1.4
	Pathology	5.7
	Pest management	3.6
	Policy	1.8
	Quarantine	0.2
	Pest resistance	0.2
	Surveillance	1.4
	Virology	0.8
Invasive animal species	Communications	1
	Population ecology	4.6
	Spatial ecology	1.8
Total		**39.3**

4.10.2. Investment

Capability investment through wages

DAFWA spends approximately $2,489,000 per annum on wages for biosecurity R&D capability across the sectors of animal health and plant health. Of this total, 69% was directed to the plant health sector and 31% to the animal health sector. No salary data was provided for the invasive animal species sector.

External funding

The department received $560,000 in external funding for plant health biosecurity R&D in 2011. Assigning external funding to national biosecurity R&D priorities and objectives, 43% of funding was against objective 1A and the remaining 57% was against objective 3A. Investors of plant health R&D included the CRCNPB and Chevron.

No external investment data was provided for the animal health or invasive animal species sectors.

4.10.3. Infrastructure

No infrastructure data was provided by DAFWA.

4.10.4. Qualitative survey – organisational focus

DAFWA provided separate responses to the questionnaire for the animal health and invasive animal species sectors. No response was received for the plant health sector.

Animal health

Future increases in DAFWA investment in animal health R&D will include recognition of and protection from new and emerging diseases, including zoonoses, and providing adequate surveillance coverage to satisfy an increasingly sensitive international market, that our products are meeting their requirements. Traditional roles in R&D are changing, and therefore overall investment is likely to decrease, and this investment is linked to reduced staff allocation to research R&D, and natural attrition of staff currently employed in a substantial R&D role through retirement and resignations. We will attempt to retain R&D investment in molecular biology and parasitology. This is contingent on external funding.

DAFWA livestock biosecurity has had a history of sound contribution to biosecurity R&D over the years, although activities in recent years have seen a decline in this area. Significant outputs over the last 10 years include:

- research into sheep and cattle internal and external (lice) parasites epidemiology, drench resistance, diagnostic tests, vaccine production and management strategies
- characterization of sheep and cattle export mortalities and management strategies
- diagnosis and epidemiology of bovine and ovine mycobacteriosis, including bovine tuberculosis, bovine and ovine Johne's disease (BJD, OJD)
- research into the epidemiology, diagnosis and control (including management strategies and vaccines) of lupinosis, annual ryegrass toxicity, botulism, neospora, caseous lymphadenitis (cheesy gland), caprine arthritis encephalitis dermatophylosis

(fleece rot), big liver spleen disease of chickens and porcine circovirus infection in pigs
- disease modelling and surveillance efficacy analysis, including risk assessment (BJD and others)
- fish pathogen characterization and diagnosis
- collaborative information management through Australian Biosecurity Intelligence Network (ABIN)
- new and significant disease characterization and diagnosis, particularly in the area of plant, fodder and other toxicosis and emerging infectious diseases (ostrich fading syndrome and others).

The top ten outputs in biosecurity R&D are as follows:

- general surveillance data/information, Information systems
- epidemiological based risk assessment and surveillance assessment
- national leadership for lupinosis (phompsin) diagnosis
- international leadership in vaccine production for haemonchosis (barber pole worm) of sheep and
- disease modelling – to identify gaps in knowledge and research priorities.

DAFWA takes national and international leadership roles in risk analysis, and in R&D in Mekong countries. Currently DAFWA is providing international leadership in vaccine production for haemonchosis (barber's pole worm) of sheep and national leadership for lupinosis (phompsin) diagnosis. In the recent past it has provided national and international leadership in the diagnosis of mycobacterial diseases of stock and epidemiological based risk assessment and surveillance assessment.

National partnerships in R&D with DAFWA include national governments in research areas above, AusVet Animal Health Services and Murdoch University. Our current international partner in development of a haemonchosis vaccine is the Mordon Research Institute in Scotland.

DAFWA identified their areas of excellence as risk analysis, training and education, and international partnerships for research. The scientific discipline areas include the application of molecular biology techniques to disease investigation and diagnosis (real time PCR and others), toxicology, parasitology, nutritional and biochemical analysis, fish pathogen identification, risk assessment and modelling, in-depth veterinary pathology investigation, information management (laboratory information system management).

Invasive animal species

DAFWA see their future investment in biosecurity R&D staying the same. Their top ten outputs in biosecurity R&D include:

- wild dog impact assessment methods
- wild dog baiting method efficacy
- starling diet analysis
- starling sound recording for surveillance
- vertebrate pest incursion response
- RHD-boost monitoring

- bedstraw eradication options
- gorse seed viability reduction

DAFWA take a national leadership role through Incursion Response Coordination through the Invasive Animals CRC – to be based in Perth. Their areas of excellence are in eradication and control methods.

4.11. Western Australian Government: Department of Fisheries

4.11.1. Human Capability

Fisheries WA employ a total of 6.6 FTEs in biosecurity R&D across the sectors of animal health and invasive marine species (Figure 76). The majority of FTEs (88%) were in the invasive marine species sector (Figure 76).

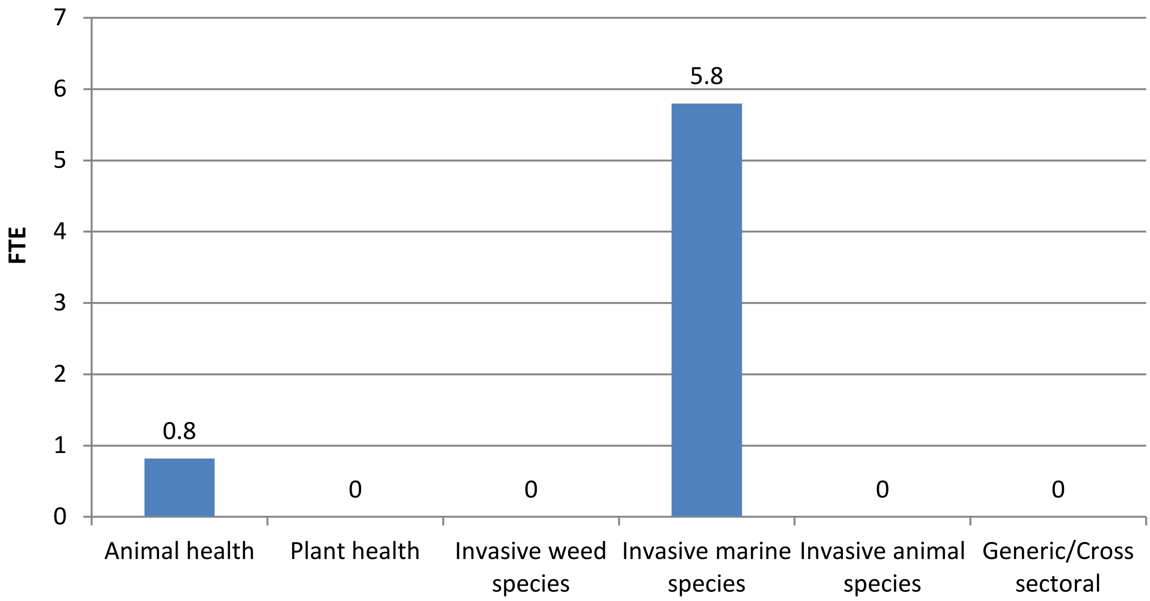

Figure 76. Full time equivalent (FTE) staff in biosecurity R&D by sector

Age

The age distribution across the biosecurity sectors shows the majority of capability (88%) was less than 40 years of age. The remaining capability was spread among staff between 40 and 55 years of age (7%) and over 55 years of age (5%; Figure 77).

For the animal health sector, 61% of capability was less than 40 years of age and 39% was over 55 (Figure 77). There was no capability between 40 and 55 years of age (Figure 77).

For invasive marine species, 91% of capability was less than 40 years of age, and the remaining 9% were between 40 and 55 years of age (Figure 77). There was no capability over 55 years of age (Figure 77).

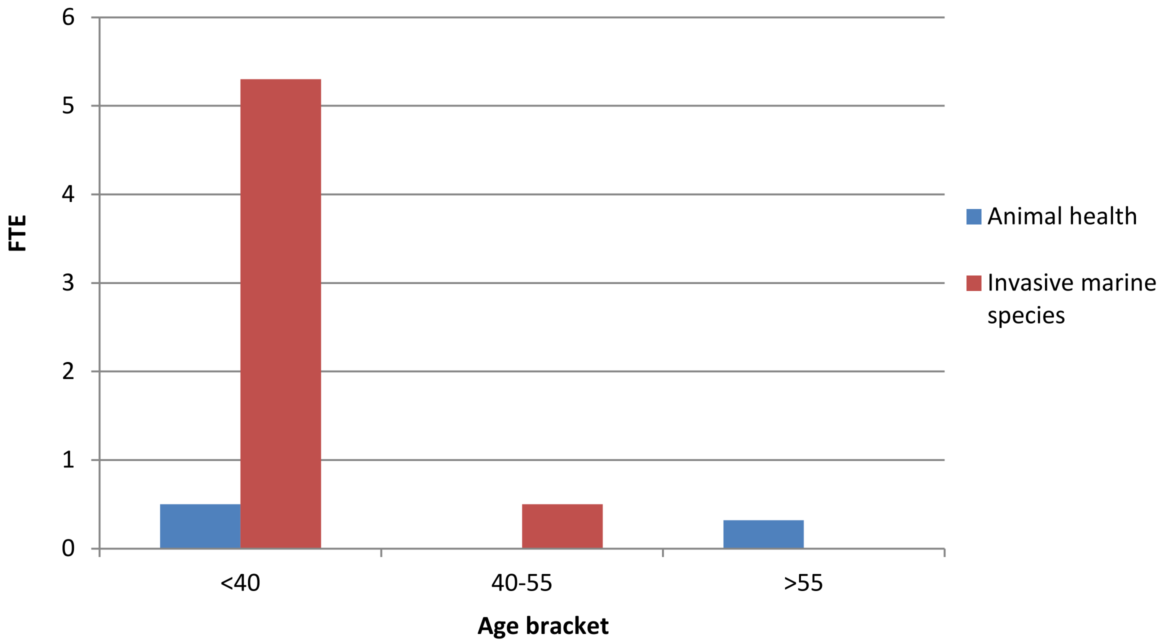

Figure 77. Full time equivalent (FTE) staff in biosecurity R&D by age bracket

Research role

The predominant research role in biosecurity R&D in Fisheries WA was researcher, accounting for 67% of research effort. The remaining effort is provided by technicians (18%) and post-doctoral researchers (15%; Figure 78). No capability is provided by postgraduate researchers (Figure 78).

For the animal health sector all the capability is provided by researchers (Figure 78). In contrast, capability in the invasive marine species sector is spread between researchers (62%), technicians (21%) and post-doctoral researchers (17%; Figure 78).

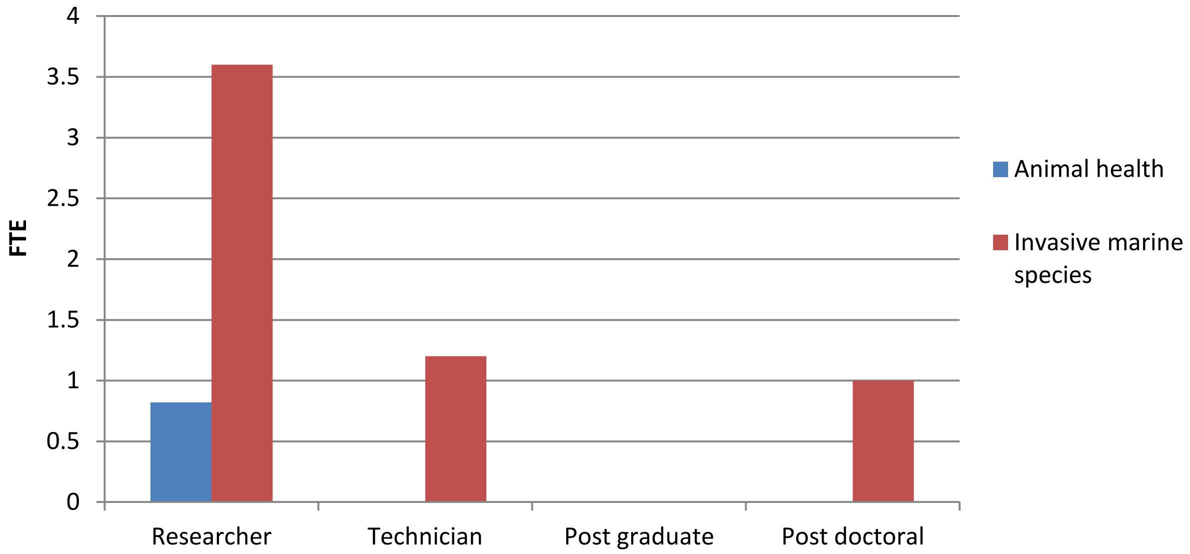

Figure 78. Full time equivalent (FTE) staff in biosecurity R&D by research role

Capability against priority area

FTEs collected against the national biosecurity R&D priorities and objectives (see Appendix A) show that Fisheries WA spent the majority (84%) of its R&D effort against priority 1 (Figure 79). Within priority area 1, the greatest amount of effort was spent against objectives 1B (42%), 1D (25%) and 1E (25%; Figure 79). Both the animal health and invasive marine species sectors conducted R&D against objectives 1A and 1B, however only invasive marine species conducted R&D against objectives 1D and 1E (Figure 79). No sectors conducted R&D against objective 1C (Figure 79).

A total of 6% of R&D effort was against priority 2 and all this effort was against objective 2B (Figure 79). Only the invasive marine species sector conducted R&D against this objective (Figure 79). No R&D effort was spent against objectives 2A, 2C or 2D (Figure 79).

Priority 3 accounted for 6% of total R&D effort, and all this effort was against objective 3A (Figure 79). Only the invasive marine species sector conducted R&D against this objective (Figure 79). No R&D effort was spent against objective 3B (Figure 79).

Priority 4 accounted for only 4% the total R&D effort and the invasive marine species sector conducted all the R&D against this priority (Figure 79).

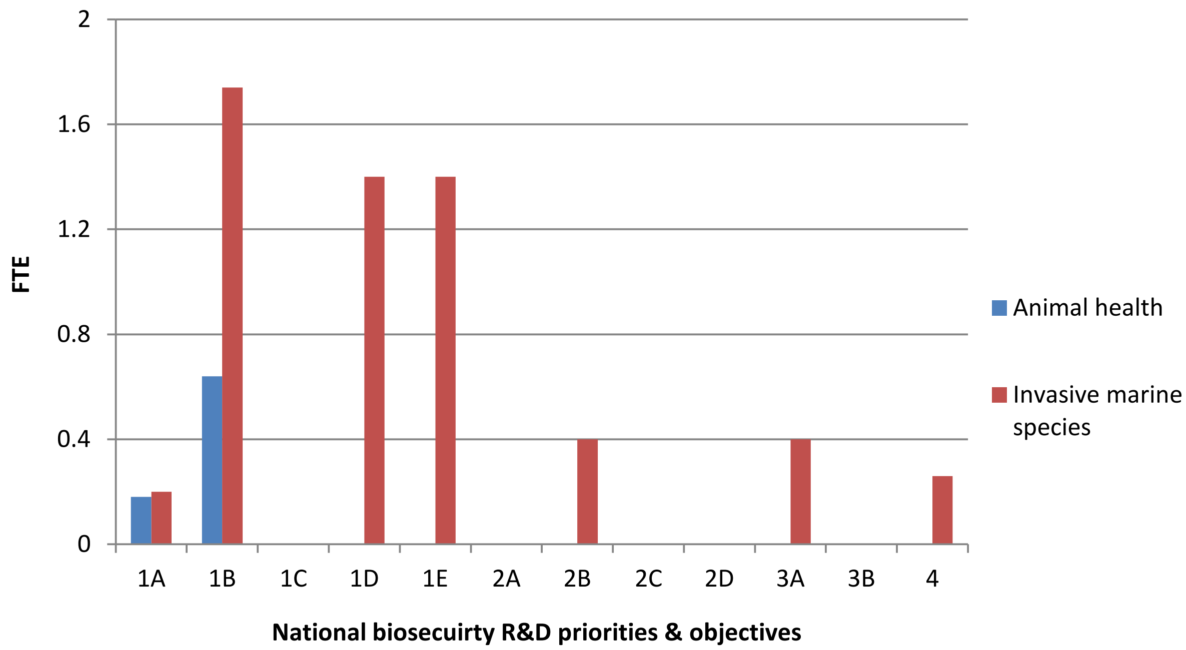

Figure 79. Full time equivalent (FTE) staff in biosecurity R&D by priorities and objectives

Discipline

FTEs were collected against disciplines (Table 34). For animal health, the greatest capability was in molecular science, accounting for 61% of FTEs. The remainder was spread between anatomical pathology (32%) and risk assessment (7%; Table 34). For the invasive marine species sector, capability was spread between molecular biology (31%) and surveillance (69%; Table 34).

Table 34. Full time equivalent (FTE) staff in biosecurity R&D by discipline

Biosecurity sector	Discipline	FTEs
Animal health	Anatomical pathology	0.3
	Molecular science	0.5
	Risk assessment	0.1
Invasive marine species	Molecular biology	1.8
	Surveillance	4.0
Total		**6.6**

4.11.2. Investment

Capability investment through wages

Fisheries WA spend approximately $581,800 per annum on wages for biosecurity R&D capability across the sectors of animal health and invasive marine species. Of this total, 15% was directed to the animal health sector and 85% to the invasive marine species sector.

External funding

Fisheries WA received $150,000 in external funding for animal health biosecurity R&D in 2011. Assigning external funding to national biosecurity R&D priorities and objectives, 53% of funding was against objective 1A, and the remaining 47% was against objective 1B. The only external investor in animal health R&D was FRDC.

No external investment data was provided for the invasive marine species sector.

4.11.3. Infrastructure

Infrastructure investments in the last 5 years (2007 – 2011) for the animal health sector of Fisheries WA included a laser microdissection microscope, at a value of $100,000, and a real-time PCR machine valued at $30,000. This infrastructure was located in South Perth.

Infrastructure investments for animal health forecast for the next 5 years (2012 – 2016) include a -80^{o}C freezer located in South Perth and valued at $30,000.

Infrastructure investments in the last 5 years (2007 – 2011) for the invasive marine species sector included molecular laboratory facilities in Perth, valued at $100,000.

Infrastructure investments for invasive marine species that are forecast for the next 5 years (2012 – 2016) include further enhancements to the molecular laboratory in Perth valued at $50,000.

4.11.4. Qualitative survey – organisational focus

Fisheries WA provided separate responses to the questionnaire for the animal health and invasive marine species sectors.

Animal health

Fisheries WA see their future investment in animal health biosecurity R&D staying the same. Their top ten outputs in biosecurity R&D include risk assessments, new diagnostic techniques for existing agents and diagnostic techniques for new and emerging pathogens.

The Department of Fisheries do not provide a national or international leadership role in biosecurity R&D as they are primarily a diagnostic laboratory. Their areas of excellence include mollusc diagnostic pathology and fish diagnostic pathology.

Invasive marine species

Fisheries WA see their future investment in invasive marine species biosecurity R&D staying the same, considering there has been recent large scale investment.

The organisation's top 10 outputs include:

- Likelihood analysis to identify vector/introductory mechanism pathways associated with ports
- Research into methods to contain and remove/reduce biofouling (eg. by wrapping of vessels or pylons/submerged structures)
- Research to identify marine pests of significance/most concern to state.
- Development of molecular and taxonomic tools to aid in marine pest detection and ID
- Development of improved sampling methodologies
- Evaluating efficacy of existing sampling/monitoring methods
- Development of methods to determine origin and spread pathways of marine pests
- Examination of secondary vectors pathways and biofouling
- Examination of pest biology in introduced environs

Fisheries WA provide a national/international leadership role in biosecurity R&D through representation on the Marine Pest Sectoral Committee, Monitoring Design Assessment Panel (MDAP), and Consultative Committee on Introduced Marine Pest Emergencies (CCIMPE), and provision of advice to Ports Australia regarding biofouling issues.

Major international partnerships in biosecurity R&D include research collaborations with National Institute of Water and Atmospheric Research (NIWA), Defence Science and Technology Organisation (DSTO), University of Western Australia, and Murdoch University.

The Department's areas of excellence include design and implementation of national system monitoring designs as well as molecular pest ID and study.

5. Appendices

5.1. *Appendix A: Intergovernmental Agreement on Biosecurity – Schedule 8*

NATIONAL BIOSECURITY RESEARCH, DEVELOPMENT AND EXTENSION FRAMEWORK

The following priority reform areas have been identified for collaborative effort over the near-term.

Outcome	Policy directions	Priority reform areas
A robust and integrated national biosecurity research and development capability and infrastructure to collaboratively support the management of biosecurity risks.	A national biosecurity research, development and extension strategy will allow for: • The investigation and application of available international and domestic leading edge technology; • The delivery of cost effective and efficient research and development that minimises the unnecessary duplication of effort, capability and infrastructure across jurisdictions; • Development and maintenance of scientific and technical capacity in nationally important areas of research and development (including linkages to international capability); • Timely and accurate identification and management of potential and emerging biosecurity risks; • Improved strategies for adoption of biosecurity research outcomes; • Identification of emerging technologies and the stimulation of new ideas, concepts and innovations; • Identification and addressing of knowledge gaps in the system; and • Greater use of internationally recognised researchers and expertise.	Implement a multi-disciplinary system to ensure research and development activities are coordinated and aligned with biosecurity priorities. Implement an adoption and extension strategy for biosecurity research outcomes. Develop programs and tools to facilitate rapid uptake of research and development outputs and adoption of innovation. Establish processes to better gather intelligence, improve modelling and analysis and translate these to action. Develop national tools and products to improve accessibility to research information and capability. Develop and implement a research and development framework where individual governments will perform: • a leadership role in biosecurity research and development where there is a major priority for the relevant government; and • a support role and effective linkages in research areas where they are not leaders.

The Parties will work together to improve the National Biosecurity System, noting that the rate of progress in many areas may be contingent on available resources and parliamentary processes.
The policy directions and priority reform areas identified in this schedule aim to achieve the principles, and improve the components and features, of the National Biosecurity System (as identified in clauses 4.1, 5.2 and 5.3 in the Intergovernmental Agreement on Biosecurity).

5.2. *Appendix B: Scope of National Biosecurity RD&E Capability Audit*

Table 35. Biosecurity sectors to be audited

<table>
<tr><th>Plant Health</th><th>Weeds</th><th>Animal Health</th><th>Invasive animal species</th><th>Invasive marine species</th></tr>
<tr>
<td>For example

Production crops:
Broad acre (including native and improved pastures
Horticulture
Forestry and timber products
Nursery production
Floriculture
Freshwater aquatic plant health impacting primary production
Bees (bee pests, diseases and invasive bees)</td>
<td>For example

Terrestrial weeds
Production weeds
Environmental weeds impacting production crops</td>
<td>For example

Production animals:
terrestrial (including horses)
Aquatic:
aquaculture
commercial wild catch fisheries
recreational fisheries
indigenous fisheries
Wildlife including aquatic animals
Zoo and aquarium animals
Companion animals</td>
<td>For example

Vertebrates:
terrestrial (e.g. rabbits, foxes etc but also including feral domestics e.g. wild dogs, horses, camels etc)
aquatic – pest fish (fresh water)
Invertebrates (e.g. bees, ants etc ...)
Fresh water invertebrates</td>
<td>For example

Marine animals
Marine plants/weeds
Biofouling and ballast water</td>
</tr>
</table>

NB: The lists under each biosecurity sector heading are not exhaustive but give an indication of the scope of the audit.

Table 36. Scope of biosecurity research and development to be included

In Scope	Out of Scope
Research and development	Extension
Laboratory diagnostics including: • Research and development • diagnostic investigation	Routine diagnostics (not linked to R&D or to diagnostic investigation, e.g. routine testing)
Pests and diseases of animals, plants and the environment including invasive species	Product integrity (e.g. residues)
Human health where it is affected by pests and diseases of animals or plant	Animal welfare
Breeding for pest/disease resistance	Non-infectious genetic disease
Vectors	Pure human health
Taxonomy	Purely operational activities
Herbicides/pesticides	
Parasiticides	
Microbial food safety (production end – e.g. campylobacter, salmonella etc)	
Social sciences where they specialise in biosecurity (e.g. economics, biosecurity communications etc)	
IT development	
Operational activities that contribute to research (e.g. collecting of surveillance data as an input to R&D)	

5.3. *Appendix C: National Biosecurity Research and development priorities*

Priorities	Objectives
1. Minimise the risk of entry, establishment, or spread of pests and diseases	**1A.** Develop the knowledge base for assessing and managing the risks of new pests and diseases, invasion pathways, and the susceptibility of ecosystems to invasion, in a changing global environment. **1B.** Enhance detection, surveillance and diagnostic systems **1C.** Understand the sociological factors associated with the adoption of risk mitigation measures by stakeholders. **1D.** Develop knowledge and strategies to prevent and contain the spread of pests and diseases within national borders **1E.** Develop tools and decision-making frameworks for prevention and eradication
2. Eradicate, control or mitigate the impact of established pests and diseases	**2A.** Characterize the movement of pests and diseases through complex environments **2B.** Develop effective and integrated approaches to managing established pests and diseases of national priority **2C.** Understand risk factors that drive emergence of new pests and diseases **2D.** Understand the interaction of pests and diseases with the invaded system
3. Understand and quantify the impacts of pests and diseases	**3A.** Improve understanding of the environmental, economic, and social impacts of pests and diseases and of management activities to control them **3B.** Develop the knowledge base and protocols for managing the invasion risks posed by one sector for others
4. Cost-effectively demonstrate the absence of significant pests and diseases	**4.** Develop tools that can cost effectively demonstrate the absence of national priority pests and diseases