UK Vector Borne Disease Research, Training and Infrastructure Landscape Survey Report

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UK Vector Borne Disease Research, Training and Infrastructure Landscape Survey Report

The report summarises the data generated through the Vector Borne Disease (VBD) Research, training and Infrastructure Landscape Survey conducted by the Biotechnology and Biological Sciences Research Council (BBSRC) between September and October 2015. The report is divided into two sections:

- The current UK VBD research, training and infrastructure landscape;
- Horizon scanning future VBD research priorities for the next 5 - 10 years.

The key findings of the report are summarised below:

- In the UK, there is a major focus on mosquito and viral VBD research. Research on other vector species is limited.

- The survey identified five key research priorities for the next 5 to 10 years
    1. Development of **new control strategies** for VBD in particular non-chemical vector control methods such as genetic control;
    2. Increased understanding of fundamental **vector biology** and **vector ecology**;
    3. Understanding what is driving the **emergence** and **expansion** of VBDs;
    4. Increased understanding of **vector pathogen** interactions;
    5. Improved **diagnostics**, **surveillance** and **forecasting**.

- The survey identified the following five areas as potential barriers to progress
    1. Research capacity and capability in particular in **entomology, vector biology, taxonomy** and **vector ecology;**
    2. Tools and technologies in particular **genetic toolkits;**
    3. Infrastructure in particular access to **vector colonies** and **high containment facilities;**
    4. Routes for translation in particular mechanisms to support **industrial collaborations;**
    5. Public opinion in regard to the intentional release of **genetically modified organisms.**

BACKGROUND

VBD of plants, animals and humans are an emerging threat to agricultural production, conservation and human health. In recent years, many VBD have demonstrated the ability to spread beyond their previously established geographical range. Therefore, in order to assess UK preparedness, it is important to understand the current UK landscape of vector biology and VBD research, training, infrastructure and translation.

For the purposes of the survey, VBD is defined as a disease caused by a pathogen that has undergone replication, or developmental change, within an arthropod and is then transmitted to a host.

Aims of the survey

- Gain a greater understanding of the UK landscape of vector biology and VBD research capacity and capability;
- Identify the current strengths and weaknesses of UK vector biology and VBD research;
- Identify vector biology and VBD research priorities for the next 5-10 years;
- Determine the future research challenges and potential barriers to progress;
- Identify any potential gaps in the provision of training for vector biology and VBD research;
- Gain a greater understanding of the translational pipeline for vector biology and VBD research.

INTRODUCTION

The survey was advertised on the BBSRC website and by Royal Entomological Society. BBSRC received 100 responses from 39 different organisations. The majority of respondents self-classified as active researchers from Higher Education Institutes (HEIs) or Research Institutes (92). In addition, five responses were also received from active researchers at Government research organisations and three responses were from science policy professionals. A breakdown of the number of responses by organisation is provided in **ANNEX 1.**

1. CURRENT UK VBD RESEARCH AND INFRASTRUCTURE LANDSCAPE

1.1 Current UK Research Capacity and Capability

1.1.1 Research expertise

Responses were received from people working on plant (18), animal (48) and human (57) VBD (respondents were able to identify more than one field) (**figure 1**).

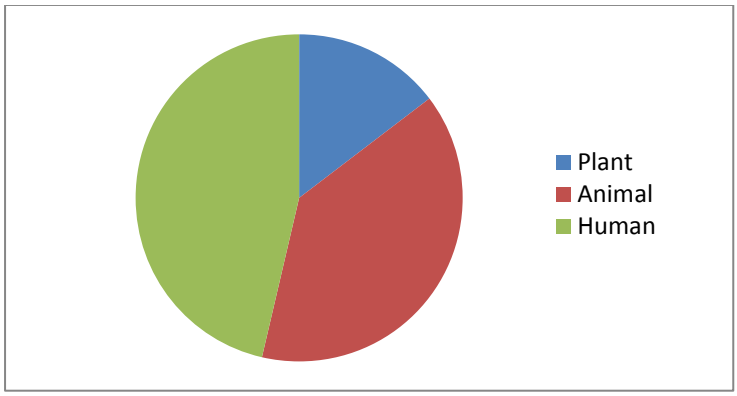

Figure 1. The proportion of survey respondents working on VBD of plants, animals and humans. Respondents were able to indicate more than one field.

The respondents reported a broad range of research expertise including vector biology, pathogen biology, interactions between the hosts, pathogens and vectors, vector ecology and epidemiology (**figure 2**).

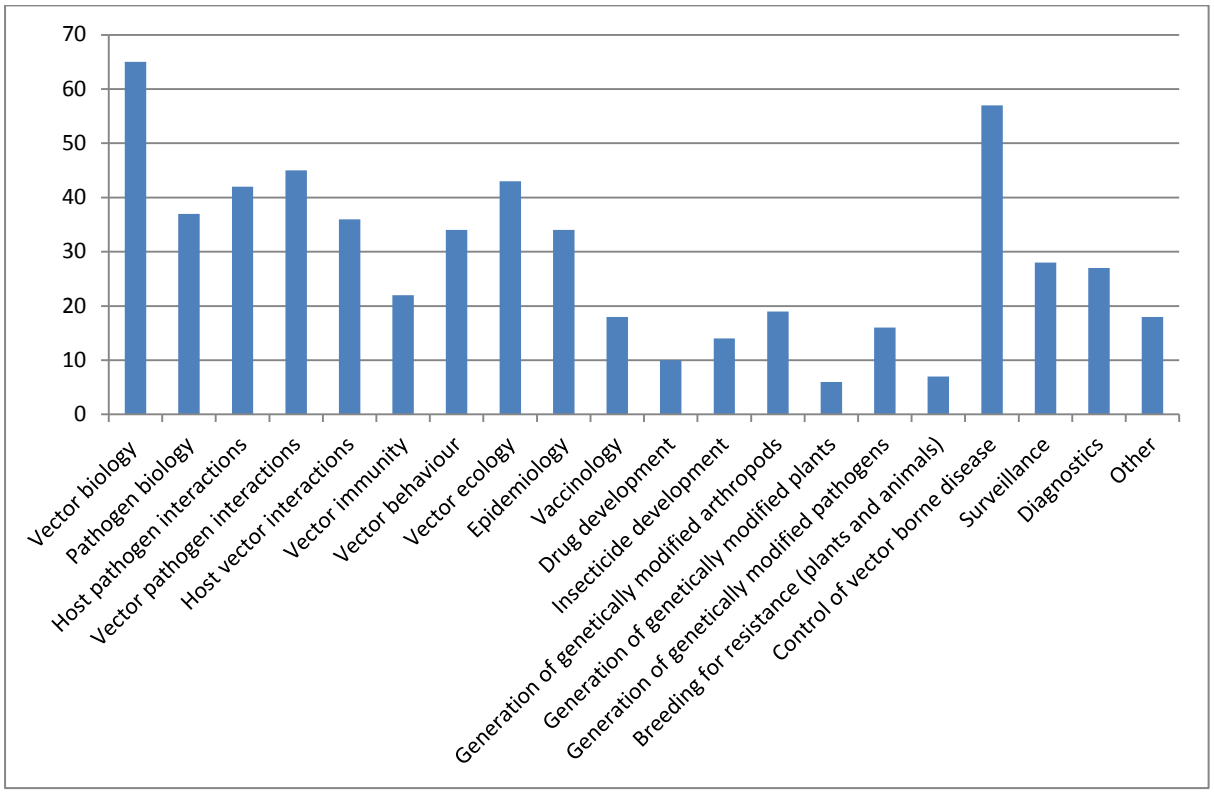

Figure 2. Number of survey respondents working in each of the research areas. Respondents were able to identify multiple areas of expertise.

1.1.2 VBD funding landscape

The respondents were asked to identify all of the agencies from which they have received, or are currently receiving, funding for vector biology and/or VBD research.

The survey results indicate that BBSRC and the Wellcome Trust are major funders of UK vector biology and VBD research (**figure 3**). The major international sources of funding are the EU programs (**figure 3**).

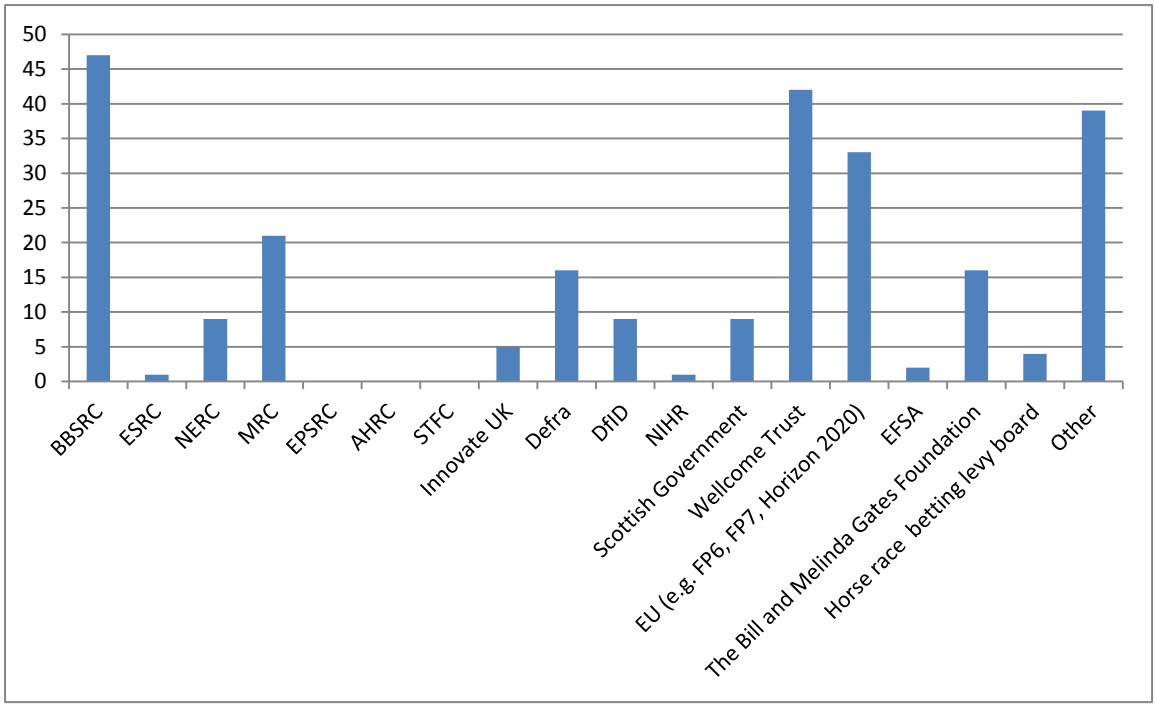

Figure 3. The numbers of researchers who have received support for VBD research from each of the funding organisation. Respondents were able to identify multiple funding agencies. The column 'Other' includes: Agriculture and Horticulture Development Board , industry, Leverhulme Foundation, Royal Society, Veterinary Medicines Agency and overseas agencies such as the World Health Organisation, National Institutes of Health and Human Frontiers Science Program.

1.1.3 Research on arthropod vectors

Respondents identified up to eight arthropod vector species and indicated which formed the major or minor focus of their research. The majority of survey respondents work on mosquitoes (**figure 4**) with *Aedes aegypti* and *Anopheles gambiae* species the most frequently identified. Research on other vector species is minimal. The data suggest that the UK has capacity and capability in mosquito research, but may lack capacity and capability in other vector research areas.

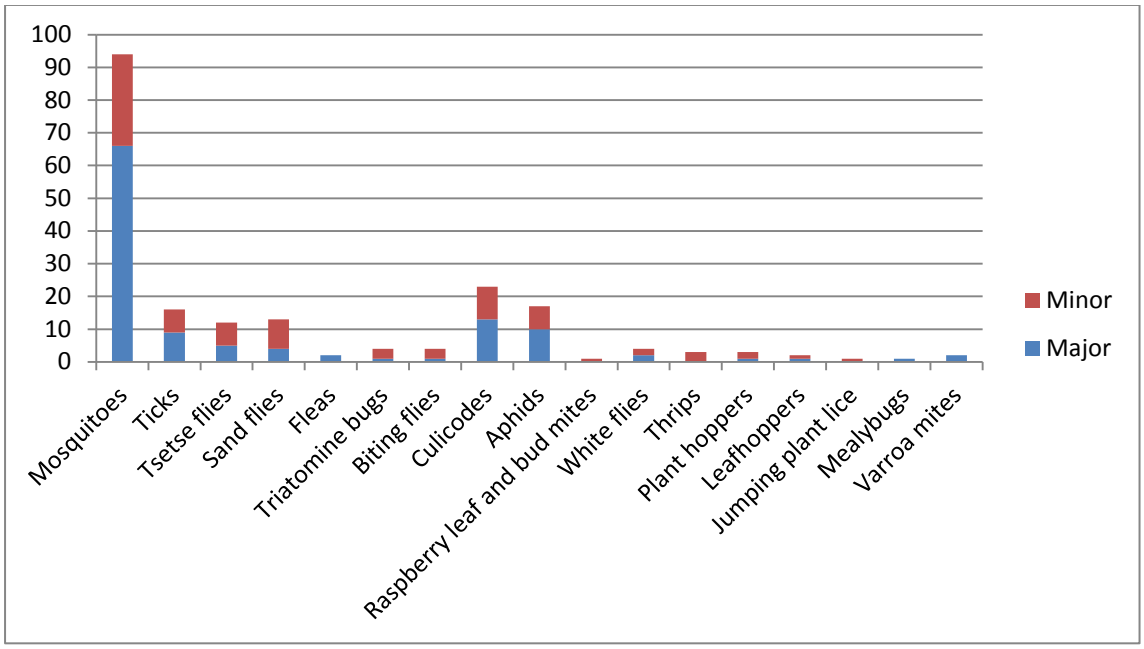

Figure 4. The numbers of respondents who are working on specific vector species. The research is identified as either a major or minor focus. Respondents were able to identify up to eight vector species.

1.1.4 Research on vector borne pathogens

Respondents identified up to eight vector borne pathogens which were either a major or a minor focus of their research. The data demonstrate that viruses are the most commonly studied vector borne pathogens, followed by protozoa, bacteria and nematodes (**figure 5**).

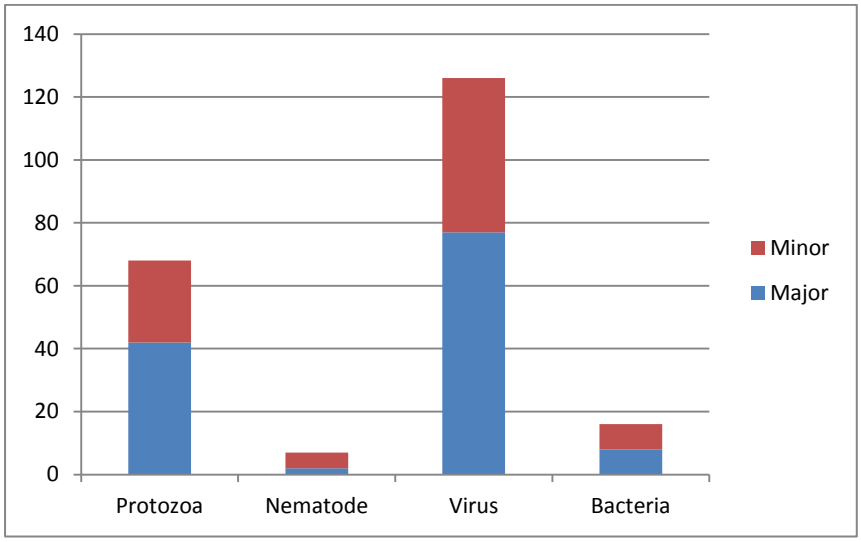

Figure 5. The numbers of respondents who are working on specific types of vector borne pathogens. The research is identified as either major or minor focus. Respondent were able to identify up to eight pathogens.

Further analysis of the data demonstrate that research into vector borne viruses covers a number of virus families (**figure 6**) but is predominantly focussed on:

- Flaviviruses (in particular, dengue virus, West Nile fever virus and Japanese encephalitis virus);
- Bunyaviruses (in particular, Rift Valley fever virus and Schmallenberg virus);
- Reoviruses (in particular, bluetongue virus and African horse sickness virus);
- Togaviruses (in particular, Chikungunya virus).

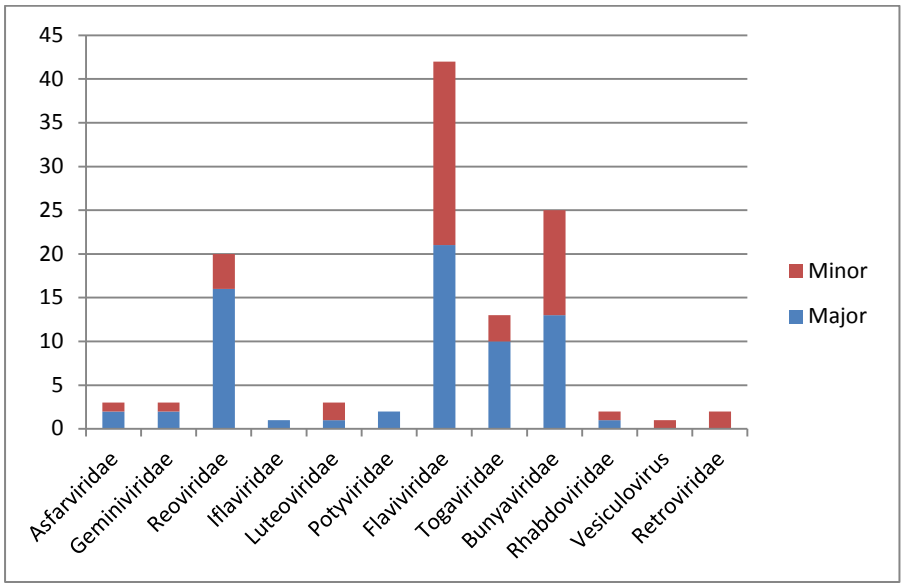

Figure 6. The numbers of respondents who are working on vector borne viruses. Research is identified as either a major or minor focus.

Further analysis of the research on vector borne protozoa shows that the largest proportion of research focuses on Plasmodium spp (**figure 7**).

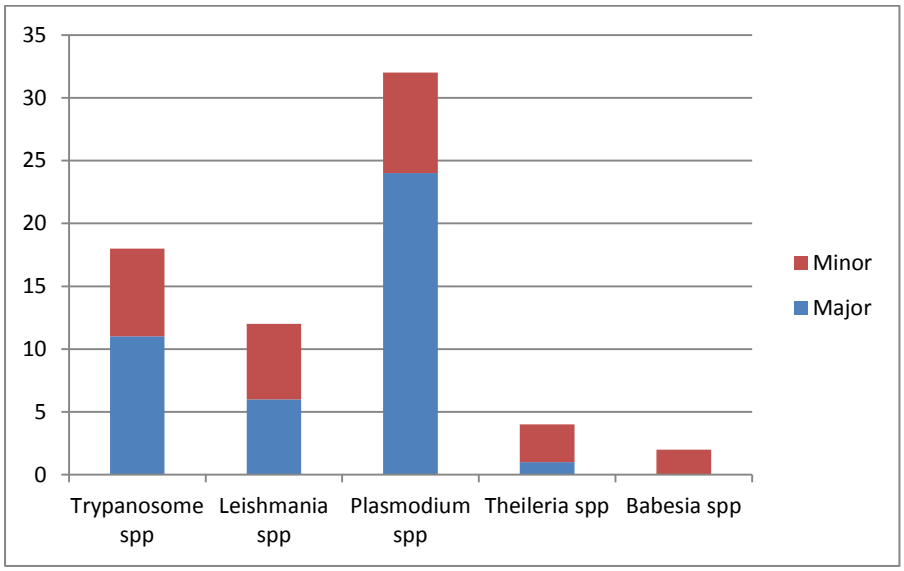

Figure 7. The numbers of respondents who are researching vector borne protozoa. Research is identified as either a major or minor focus.

1.2 Current UK Infrastructure

1.2.1. Arthropod colonies

The survey identified 27 UK organisations that have facilities for housing arthropods. A summary of the number of each type of vector colony is provided in **table 1**; the full list is available in **ANNEX 2**. A number of respondents indicated that facilities at their organisation may have the capacity to provide arthropods to external users.

Table 1. Number of organisations with specific vector colonies

	Mosquito	Tsetse fly	Sand fly	Tick	Triatomine	Midge	Stable fly	Flea	Aphid	Whitefly	Thrip	Mealybug	Leafhopper	Planthopper	Mite
Number of organisations	16	2	6	5	1	2	1	1	7	3	2	1	2	2	3

1.2.2. High containment facilities

The survey identified 20 organisations with facilities for conducting research on pathogens that require high containment under Specific Animal Pathogen Order (SAPO) or Advisory Committee on Dangerous Pathogens (ACDP) regulations[1]; the full list[2] is available in **ANNEX 3**.

Of the organisations that responded:

- The Animal Plant Health Agency and the Pirbright Institute were identified as the only organisations that have SAPO4 licenced facilities for in vitro/cell culture, arthropods, and small animals.
- The Pirbright Institute was the only organisation identified as having SAPO4 licenced facilities for research on large animals.
- Public Health England is the only organisation identified as having ACDP4 licenced facilities for in vitro/cell culture, arthropods and small animals.
- Nine organisations have facilities licenced for work with arthropods to ACDP3 and seven are licenced for work with arthropods to SAP03 (**table 2**).

Table 2. The number of organisations with ACDP3 or SAPO3 licenced facilities for work with VBD pathogens.

	In vitro/cell culture	Arthropods	Small animals	Large Animals
ACDP3	13	9	11	0
SAPO3	13	7	4	1
ACDP4	1	1	1	0
SAPO4	2	2	2	1

[1] Definitions are provided in ANNEX 3.

[2] This is not an exhaustive list. Other facilities do exist, but were not captured in this survey, because either their research does not focus on VBD or researchers from those organisations did not respond to the survey.

The limited number of facilities for high containment research using arthropods may be a barrier, restricting the amount of research that can be conducted into vector pathogen interactions. Furthermore, the survey respondents also indicated that in their opinion several of these facilities lacked sufficient capacity to meet current demand.

1.3 Current UK VBD translational activities

More than half (57) of the survey respondents have had experience of translating vector biology and/or VBD research into application or policy.

Thirty-five of the respondents identified research that is currently in the process of, or has been translated into, an application that is of potential commercial relevance, examples include development of genetically modified insects, vaccines, drugs and diagnostics.

Research from 22 respondents has been utilized by Government agencies for the development of policies and/or risk analysis, examples include vector control and disease control policies.

1.4 Current UK VBD training activities

The survey identified 28 UK organisations that provide a range of education/training in vector biology and/or VBD (**figure 8**). The full list of organisations is available in **ANNEX 4**.

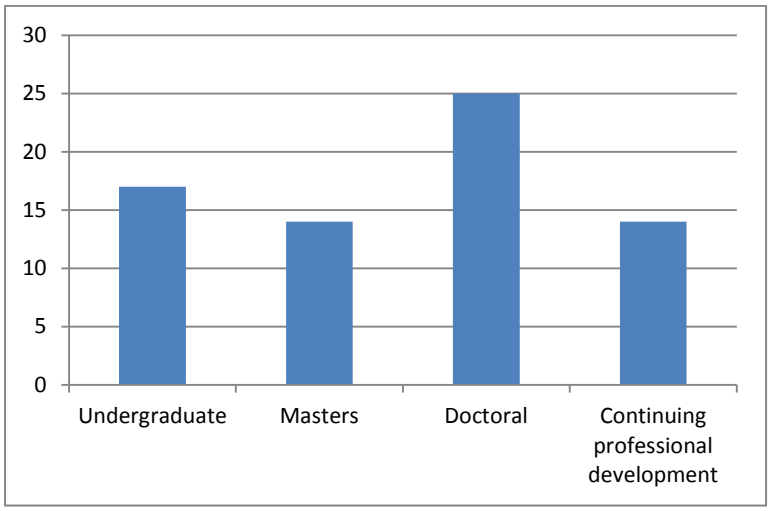

Figure 8. The number of UK organisations providing VBD training by degree level or continuing professional development.

2. HORIZON SCANNING FUTURE RESEARCH PRIORITIES AND POTENTIAL CHALLENGES/BARRIERS

The survey respondents were asked to identify:

- Key research priorities (up to 5) in vector biology and/or VBD that need to be addressed in the next 5-10 years in a national and/or international context;
- Potential challenges and barriers to achieving the priorities;
- Training requirements.

2.1 Key Research Priorities for UK VBD Research

Using the survey responses, the following 5 key research priorities have been identified for the next 5 to 10 years (**figure 9**)

- Development of **new control strategies** for VBD in particular non-chemical vector control methods such as genetic control;
- Increased understanding of fundamental **vector biology** and **vector ecology**;
- Understanding what is driving the **emergence** and **expansion** of VBDs;
- Increased understanding of **vector pathogen** interactions;
- Improved **diagnostics**, **surveillance** and **forecasting**.

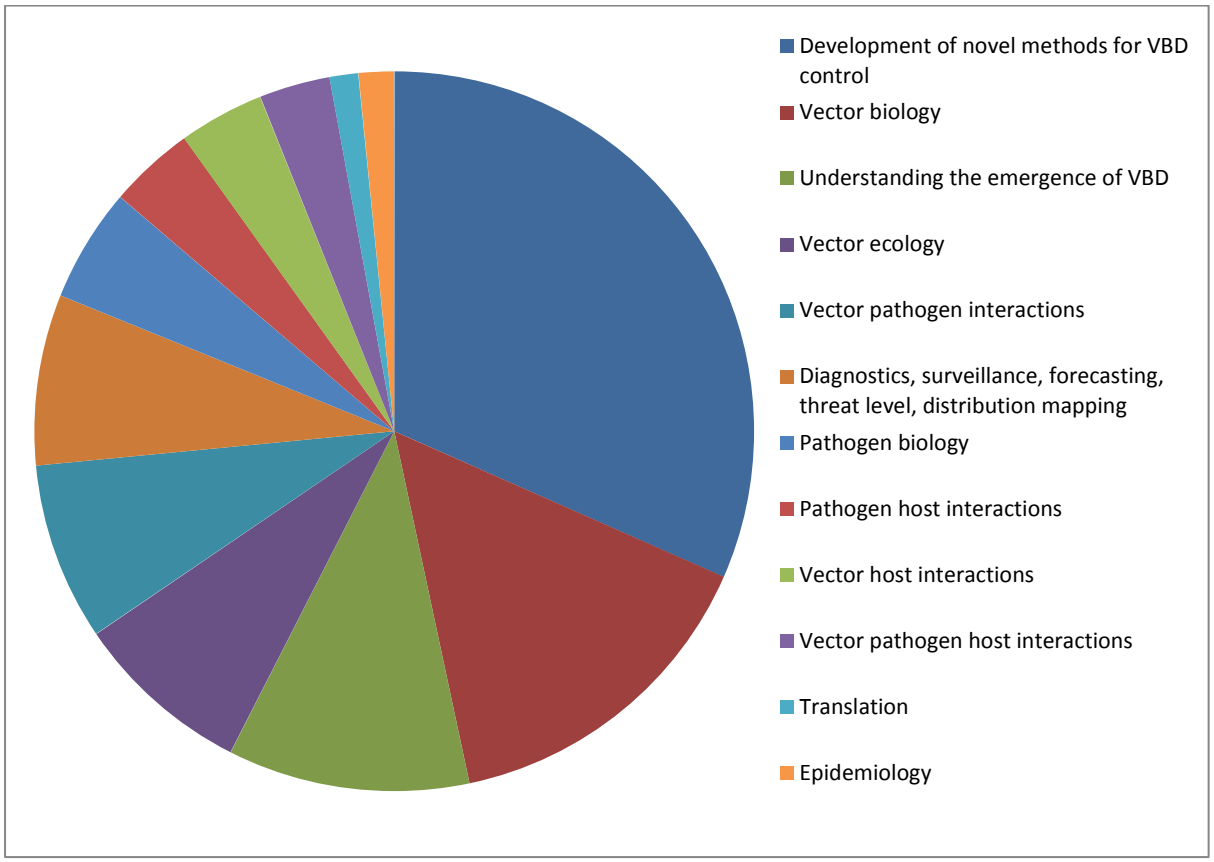

Figure 9. Research priorities identified by survey respondents. Respondents were able to identify up to 5 key research priorities.

Further analysis of the survey data demonstrates that a number of control strategies are required including vaccines, drugs, vector control, insecticides and the development of plants that are resistant to vectors and/or vector borne pathogens. The data reveal that the key research priority is the development of **novel vector control mechanisms** (**figure 10**).

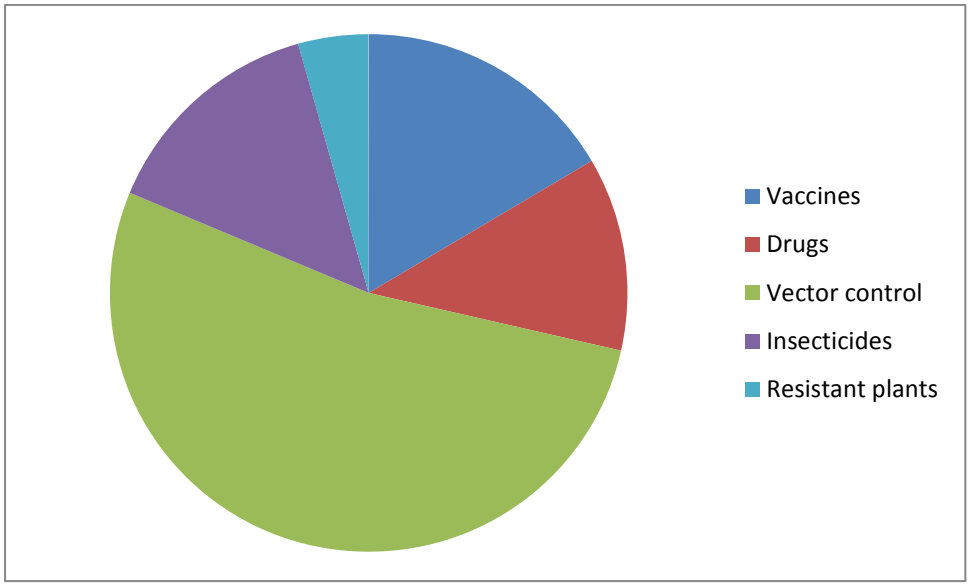

Figure 10. Specific VBD control mechanisms identified by the survey respondents.

2.2 Potential Challenges and Barriers

The respondents were asked to identify any potential challenges/barriers, which might prevent the key research priorities identified above being achieved.

Throughout this section of the survey a general theme emerged around the challenges posed by the current level of funding available for vector biology and VBD research. Respondents highlighted the need for more funding to support basic, interdisciplinary and applied research and the need for additional funding for infrastructure and training.

2.2.1 Research capacity and capability

A current lack of expertise in **entomology**, **vector biology**, **taxonomy** and **vector ecology** were identified as major challenges in terms of capacity and capability (**figure 11**).

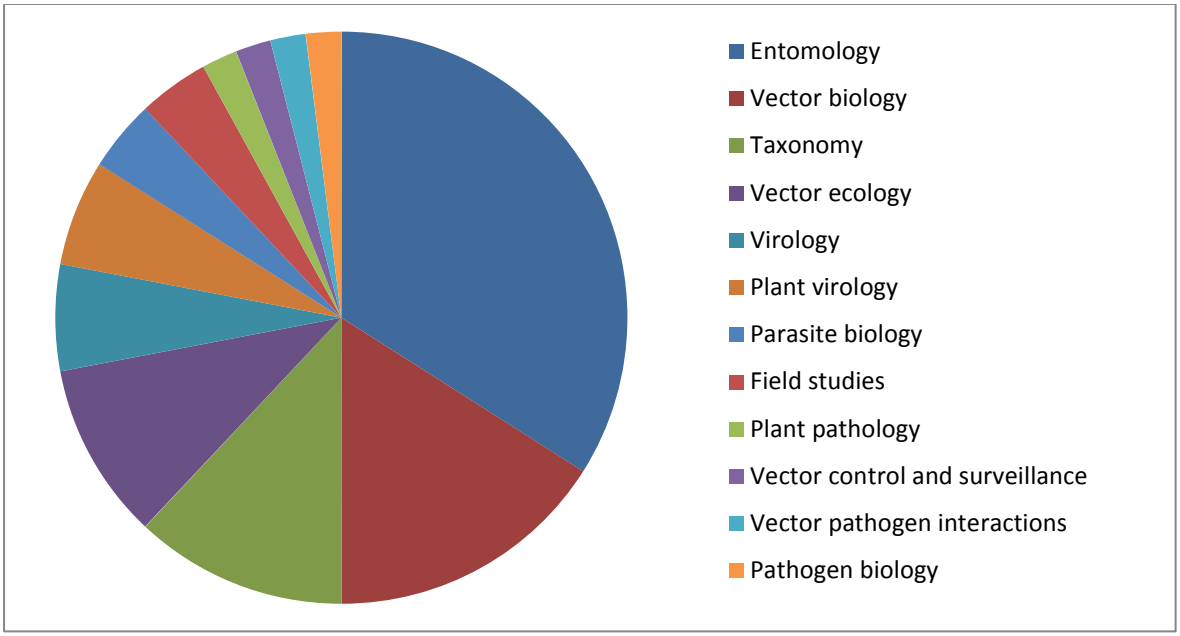

Figure 11. Research capacity and capability gap areas. Respondents were able to identify multiple barriers and challenges.

2.2.2. Tools and technologies

The survey identified the need for a **genetic toolkit** to enable genetic manipulation of vectors for functional studies and control strategies such as genome editing tools. Other important tools were: well annotated **genomic sequences** for vector species, vector **colonies** and vector **cell lines** and cultures (**figure 12**).

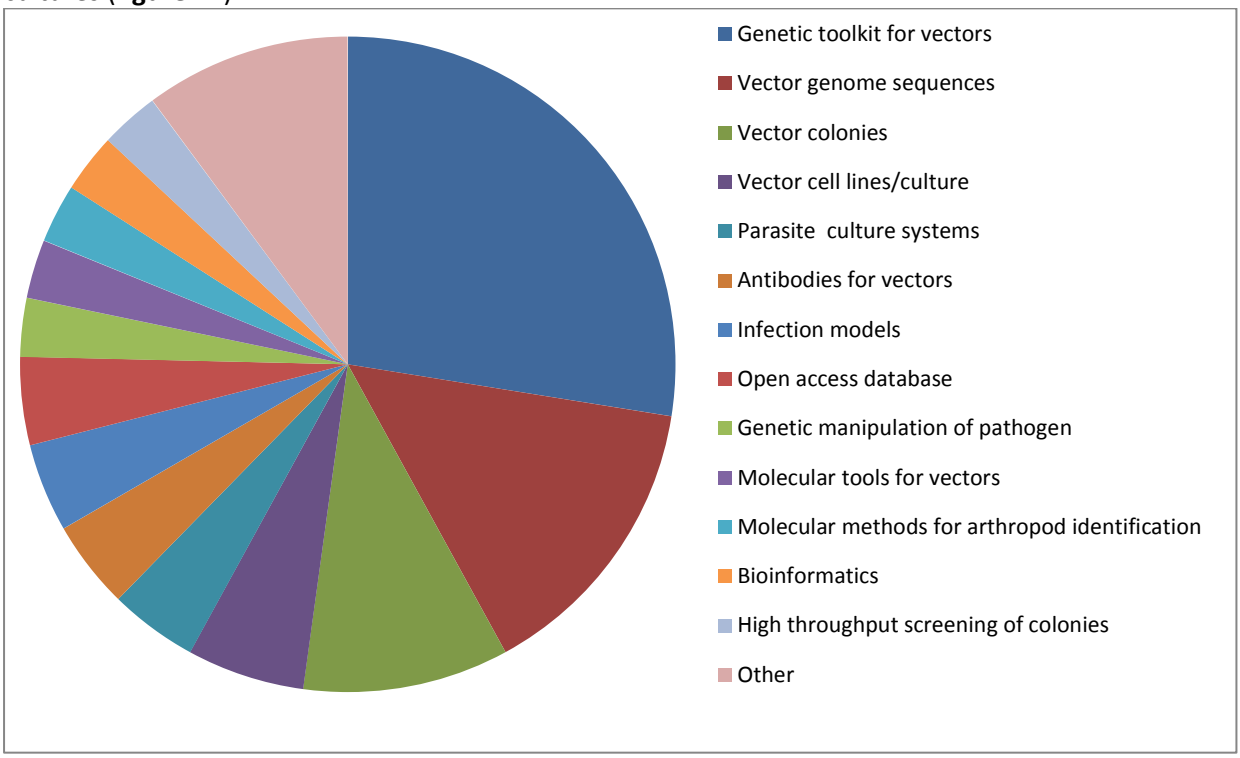

Figure 12. Challenges and barriers identified for tools and technologies. The section 'other' includes single cell technology, modelling tools, behaviour monitoring tools, surveillance tools, protein expression systems, pathogen reporter systems and tools for genetic manipulation of the host.

2.2.3 Infrastructure

The single biggest infrastructure barrier was identified as lack of **vector colonies** followed by: the lack of **high containment facilities;** the lack of a **national VBD research centre;** and access to **field sites** (**figure 13**).

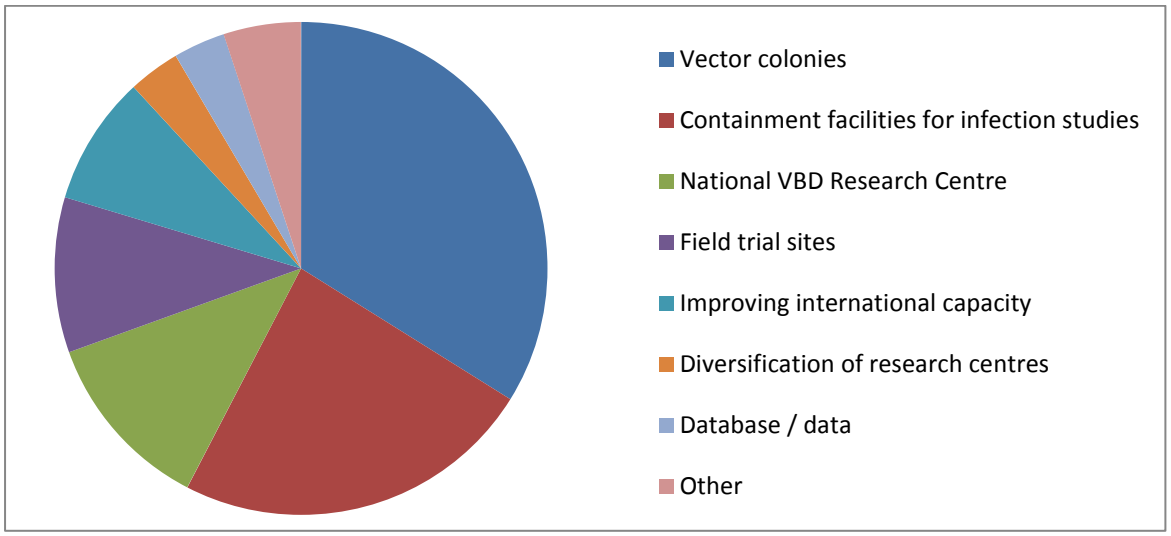

Figure 13. Challenges and barriers identified in relation to infrastructure. The section 'Other' includes equipment, infrastructure for vector behaviour studies and a network of traps. Respondents were able to identify multiple challenges and barriers.

2.2.4 Routes for translation of basic research

The survey respondents identified a need for more **funding** to support **collaborations** between **academia and industry** (**figure 14**). The survey also identified the need to develop mechanisms to increase **links** between **academics, farmers, industry and policy makers**.

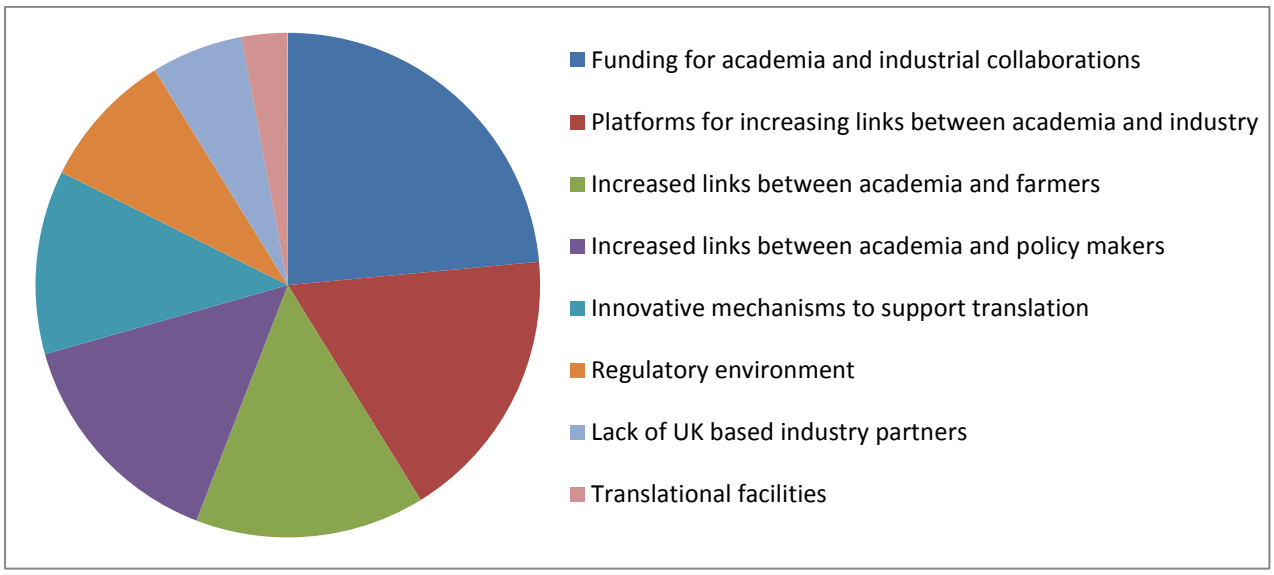

Figure 14. Challenges and barriers identified for translation of VBD research. The respondents were able to identify multiple challenges and barriers.

2.2.5 Public opinion

The survey respondents considered that potential public concern over **genetic modification** (GM) and **release of genetically modified organisms** (GMO) into the environment could be a major barrier to progress (**figure 15**) and highlighted the need to engage in **public dialogue** around these issues, especially the release of genetically modified insects and plants.

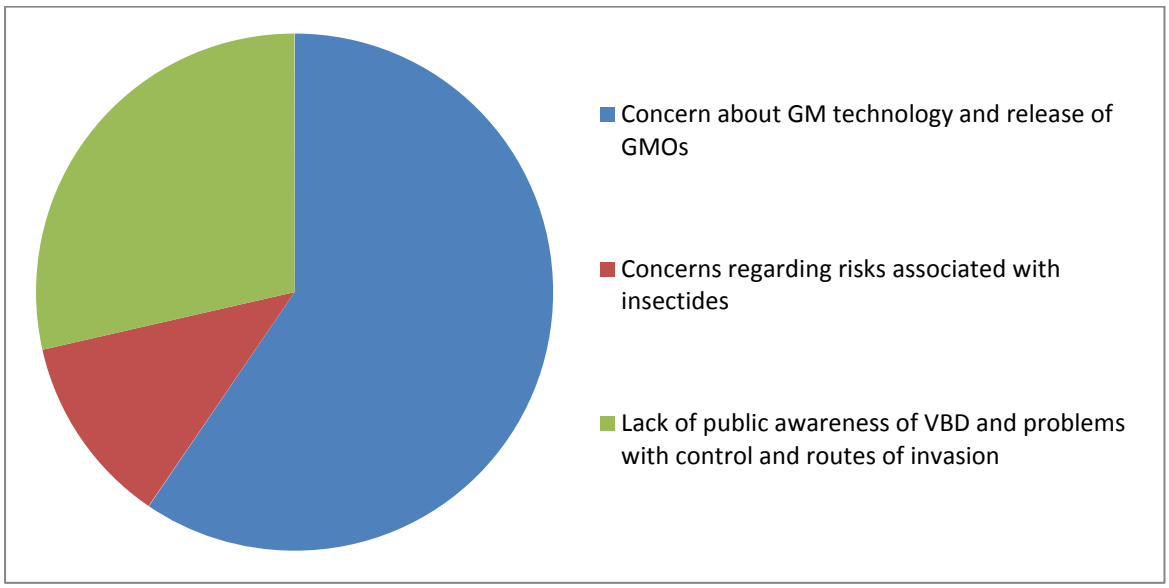

Figure 15. Potential challenges and barriers linked to public opinion. The respondents were able to identify multiple challenges and barriers.

2.3 Current strengths and weaknesses

The respondents were asked to identify the current strengths and weaknesses in the UK VBD research community.

2.3.1 Strengths

The UK VBD research community has a number of internationally recognised researchers and research groups. The UK was also identified as having particular strengths in parasitology, especially research into vectors of human disease (notably mosquitoes) and malaria research.

2.3.2 Weaknesses

Lack of funding for vector biology and VBD research in the UK was identified as a major weakness. The survey also identified weaknesses in specific research areas such as vector biology. There was concern about the small size of the research community, the thin spread of expertise and the lack of co-ordination, networking and collaboration between researchers, across disciplines and between institutions.

2.4 Future Training Requirements

The majority of respondents (54/97) felt that there are currently gaps in the provision of training in vector biology and/or VBD. Only five respondents considered the current level of training provision to be appropriate.

The respondents were asked to identify the gaps in training and these have been grouped into seven areas. The most frequently identified gaps were in the training at specific graduate/postgraduate levels and the provision of training in specific disciplines (**figure 16**).

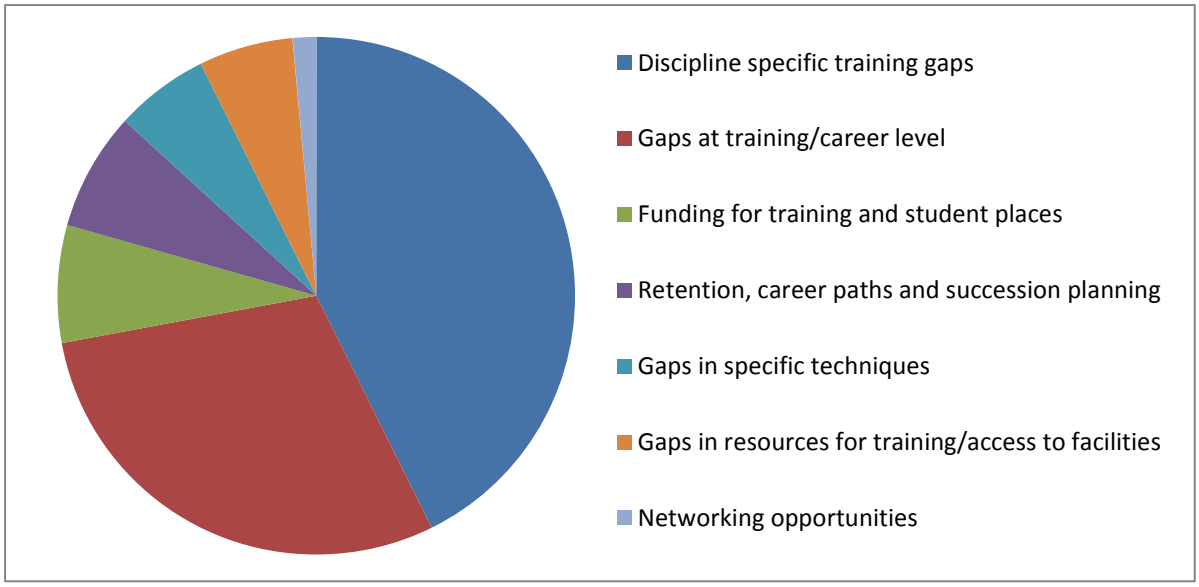

Figure 16. UK VBD training gaps as identified by the survey respondents. The respondents were able to identify multiple gaps.

Closer examination of the survey responses shows that respondents most frequently identified the provision of training at **postgraduate** level as a gap (**figure 17**).

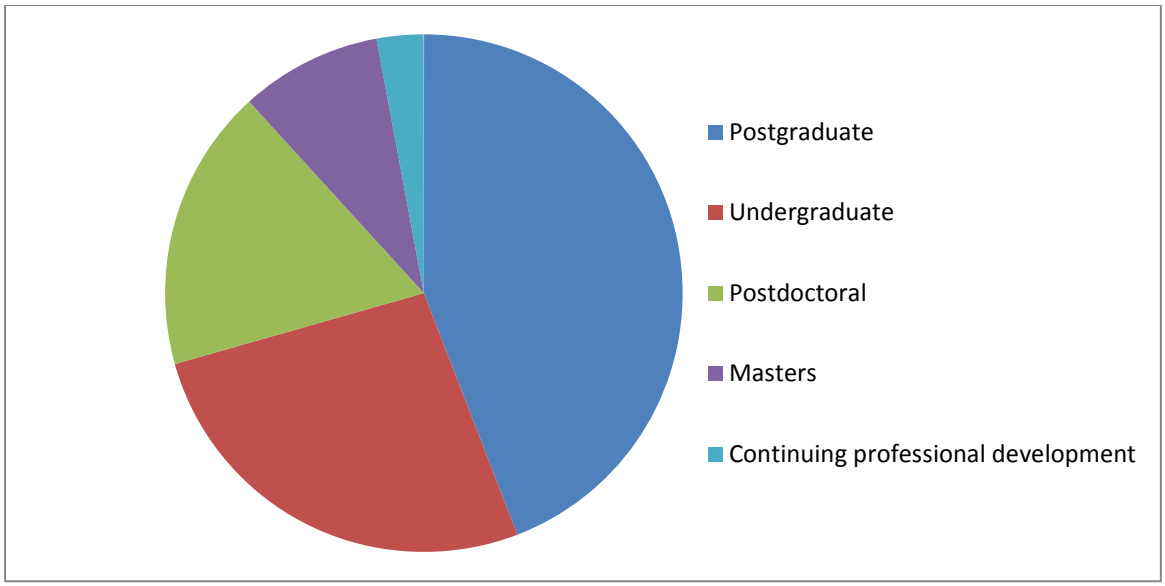

Figure 17. Gaps identified in the provision of VBD training at different education levels. The survey respondents were able to identify multiple gaps.

Examination of the survey data showed that discipline specific training gaps were most frequently identified in **vector biology, entomology** and **taxonomy** (**figure 18**). Training in **plant pathology**, **plant vector borne disease** and **plant viruses** were also identified as a gap.

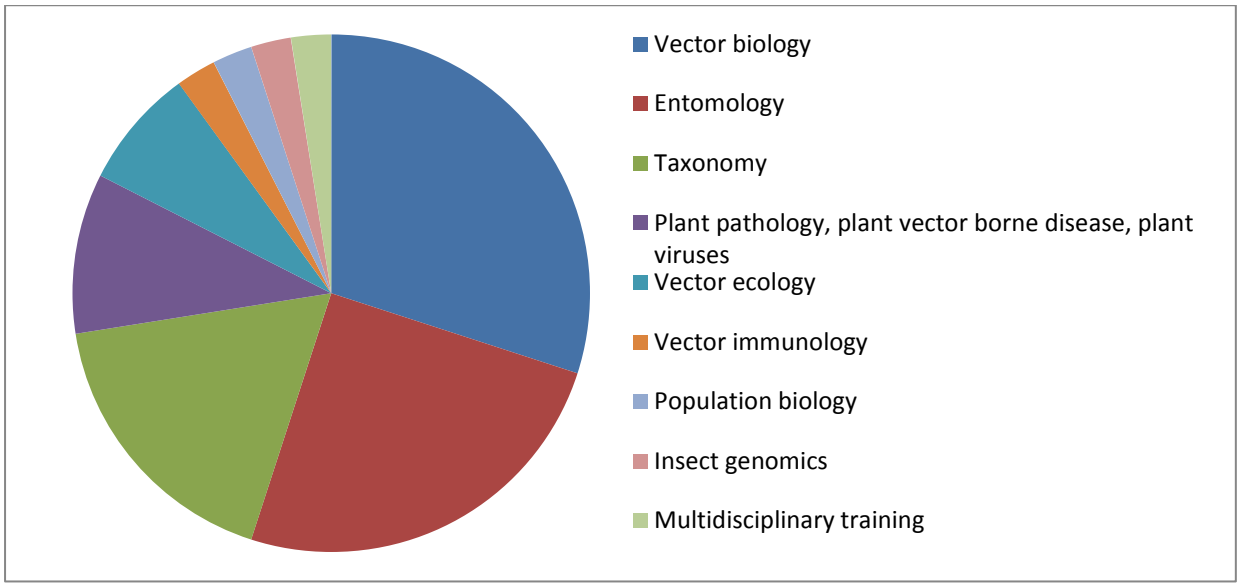

Figure 18. Discipline specific VBD training gaps identified by the survey. The survey respondents were able to identify multiple gaps.

Annex 1

Table 3. Breakdown of the number of responses from each of the responding organisations

Survey respondents were from 39 different institutions/organisations. The largest number of responses were received from the Pirbright Institute, University of Glasgow, Liverpool School of Tropical Medicine and the London School of Hygiene and Tropical Medicine.

Institution /Organisation	Number of respondents
Aberystwyth University	1
Agri-Food & Biosciences Institute (AFBI)	1
Anglia Ruskin University	1
Animal and Plant Health Agency (APHA)	1
Centers for Disease Control and Prevention	1
Department for Environment, Food and Rural Affairs (Defra)	1
Department of Agriculture and Rural Development (DARD)	1
Harper Adams University	2
Imperial College London	5
James Hutton Institute	3
John Innes Centre	1
Keele University	5
Lancaster University	2
Liverpool School of Tropical Medicine	7
London School of Hygiene & Tropical Medicine	6
National Institute for Biotechnology and Genetic Engineering	1
Natural History Museum	2
NERC Centre for Ecology and Hydrology	1
Public Health England	2
Roslin Institute, University of Edinburgh	2
Rothamsted Research	4
Salford University	1
Scottish Government	1
Swansea University	1
The Francis Crick Institute	1
The Pirbright Institute	12
University of Aberdeen	2
University of Bristol	3
University of Cambridge	2
University of Dundee	2
University of Glasgow	7
University of Greenwich	4
University of Lancaster	1
University of Liverpool	4
University of Manchester	1
University of Nottingham	2
University of Oxford	2
University of York	1
Wellcome Trust Sanger Institute	2

Annex 2

Table 4. Details of UK arthropod vector colonies

The survey identified 29 organisations that have facilities for housing arthropods. Two were international organisations (Centre for Disease Control and Prevention and National Institute for Biotechnology and Genetic Engineering) and have not been included in the survey.

Organisation	Arthropod vectors housed
Animal and Plant Health Agency	Mosquitoes
Harper Adams University	Sitobion avenae Rhopalosiphum padi Metopolophium dirhodum Myzus persicae Aphis fabae Aphis gossypii Acyrthosiphon pisum Brevicoryne brassicae Macrosiphum euphorbiae
Imperial College London	Anopheles gambiae Aedes aegypti Aedes albopictus Anopheles stephensi Anopheles arabiensis
James Hutton Institution	Aphids (numerous species) Ticks (not breeding) Mites (very low as these are difficult to maintain)
John Innes Centre	Myzus persicae Brevicoryne brassicae Acyrthosiphon pisum Sitobion avenae Rhopalosiphon padi Macrosteles quadrilineatus Dalbulus maidis Circulifer tenellus Nilaparvata lugens Bemisia tabaci
Keele University	Anopheles gambiae Other Anopheles species Aedes aegypti Lutzomyia longipalpis Thrips
Lancaster University	Aedes and Culex species Sandflies
Liverpool School of Tropical Medicine	Anopheles gambiae Anopheles arabiensis Anopheles funestus Aedes aegypti Aedes albopictus Culex quinquefasciatus Glossina mortisans Sandflies

Organisation	Arthropod vectors housed
London School of Hygiene and Tropical Medicine	Mosquitoes (Aedes aegypti, Aedes albopictus, Anopheles gambiae, Anopheles stephensi, Anopheles dirus, Anopheles arabiensis,Culex quinquefasciatus, Culex tritaeniorhynchus) - including susceptible and resistant strains Triatomine Lutzomyia longipalpis Mites
NERC Centre for Ecology and Hydrology	Aphids
Public Health England	Mosquito species (Currently not in use because of lack of funding) Ticks (Currently not in use because of lack of funding)
Rothamsted Research	Aphids Whiteflies Brown Planthoppers Varroa destructor Midges Ticks Mosquitoes
Swansea University	Mosquitoes Ticks
The Francis Crick Institute	Mosquitoes
The Pirbright Institute	Culicoides sonorensis Culicoides nubeculosus Ornithodoros moubata Anopheles gambiae Aedes aegypti Stomoxys calcitrans Culex pipiens (UK origin)
The Roslin Institute, University of Edinburgh	Rhipicephalus appendiculatus Hyalomma excavatum
University of Aberdeen	Ixodes ricinus Varroa destructor Cat fleas
University of Bristol	Tick (collect rather than bred) Tsetse (experimental not breeding)
University of Cambridge	Aedes aegypti Aphids
University of Glasgow	Anopheles gambiae Anopheles arabiensis Anopheles albimanus Aedes aegypti Glossina morsitans
University of Greenwich	Anopheles gambiae Whiteflies Aphids Mealybugs Thrips Leafhopper
University of Lancaster	Lutzomyia Aedes species Anopheles species

Organisation	Arthropod vectors housed
University of Liverpool	Mosquitoes
University of Manchester	None currently reared
University of Oxford	No details provided
University of York	Sandflies
Wellcome Trust Sanger Institute	Anopheles species

Annex 3

Table 5. Details of UK high containment facilities

The survey identified twenty organisations with high containment facilities.

Institution	In vitro/cell culture	Arthropods	Small animal	Large animal
Animal and Plant Health Agency	SAPO3 SAPO4 ACDP3	SAPO4	ACDP3 SAPO4	none
Imperial College London	ACDP3	ACDP3	ACDP3	none
John Innes Centre	none	SAPO3	none	none
Keele University	SAPO3 ACDP3	ACDP3	ACDP3	none
Lancaster University	SAPO3 ACDP3	ACDP3	none	none
Liverpool School of Tropical Medicine	SAPO3 ACDP3	SAPO3 ACDP3	SAPO3	none
London School of Hygiene and Tropical Medicine	SAPO3 ACDP3	SAPO3 ACDP3	SAPO3 ACDP3	none
Public Health England	ACDP4	ACDP4	ACDP4	none
The Francis Crick Institute	SAPO3 ACDP3	SAPO3 ACDP3	SAPO3 ACDP3	
The Pirbright Institute	SAPO3 SAPO4 ACDP3	SAPO3 SAPO4 ACDP3	SAPO3 SAPO4 ACDP3	SAPO3 SAPO4
The Roslin Institute, University of Edinburgh	No detail provided	No detail provided	No detail provided	No detail provided
University of Bristol	No detail provided	No detail provided	No detail provided	No detail provided
University of Dundee	SAPO3 ACDP3	none	SAPO3 ACDP3	none
University of Glasgow	SAPO3 ACDP3	SAPO3 ACDP3	SAPO3 ACDP3	none
University of Greenwich	No detail provided	No detail provided	No detail provided	No detail provided
University of Liverpool	ACDP3	none	ACDP3	none
University of Nottingham	SAPO3 ACDP3	none	none	none
University of Oxford	SAPO3	none	none	none
University of York	none	none	ACDP3	none
Wellcome Trust Sanger Institute	SAPO3 ACDP3	SAPO3 ACDP3	ACDP3	none

Definitions of the different containment levels and examples of some vector borne pathogens that require high containment facilities

Specified Animal Pathogen Order (SAPO)

- Group 2 – Disease producing organisms which are either exotic or produce notifiable disease, but have a low risk of spread from the laboratory, e.g., Babesia, Theileria, Trypanosome.
- Group 3 – Disease producing organisms which are either exotic or produce notifiable disease and have a moderate risk of spread from the laboratory, e.g., African horse sickness virus, bluetongue virus, equine infectious anaemia virus, Japanese encephalitis virus, West Nile virus, Rift Valley fever virus
- Group 4 – Disease producing organisms which are either exotic or produce notifiable disease and have a high risk of spread from the laboratory, e.g., African Swine fever virus

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- Group 2 - Can cause human disease and may be a hazard to employees; it is unlikely to spread to the community and there is usually effective prophylaxis or treatment available, e.g., Bartonella, Borrelia, Brugia malayi, Babesia
- Group 3 - Can cause severe human disease and may be a serious hazard to employees; it is may spread to the community but there is usually effective prophylaxis or treatment available, e.g., Rickettsia, Leishmania donovani, Plasmodium falciparum, Dengue viruses
- Group 4 - Causes severe human disease and is a serious hazard to employees; it is likely to spread to the community and there is usually no effective prophylaxis or treatment available, e.g., Crimean Congo haemorrhagic fever virus.

Annex 4

Table 6. Provision of UK vector biology and/or VBD training

The following organisations were identified as providing vector biology and/or VBD training.

Organisation	Training provided				
	Undergraduate	Masters	Doctoral	Continuing professional development	Other
Agri-Food & Biosciences Institute			X		
Animal and Plant Health Agency			X		
Harper Adams University	X	X	X	X	
Imperial College London	X	X	X	X	
James Hutton Institute	X	X	X	X	
John Innes Centre		X	X	X	X
Keele University	X	X	X		
Lancaster University	X	X	X		
Liverpool School of Tropical Medicine	X	X	X	X	
London School of Hygiene & Tropical Medicine		X	X	X	
Natural History Museum			X	X	
NERC Centre for Ecology and Hydrology			X		
Public Health England		X	X	X	
Rothamsted Research			X	X	
Salford University			X		
Swansea University	X				
The Francis Crick Institute				X	
The Pirbright Institute	X	X	X	X	
University of Aberdeen	X		X		
University of Bristol	X	X	X		
University of Cambridge	X		X		
University of Dundee	X		X		
University of Glasgow	X	X	X	X	
University of Greenwich	X	X	X	X	
University of Liverpool	X	X	X	X	
University of Nottingham	X		X		
University of York	X				
Wellcome Trust Sanger Institute	X		X		