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REVIEW ARTICLE

One Health research and training in Australia and New Zealand

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Purpose of the review: This review was performed to create a repository of information on One Health research and training in Australia and New Zealand (ANZ). The review sought to determine 1) how many training activities there are in ANZ, 2) how much research on zoonotic diseases is undertaken by multidisciplinary teams, and 3) how collaborative and integrated they are.
Recent findings: There are few opportunities for training in One Health in ANZ. The majority require enrolment in a postgraduate degree programme, and there is only one postgraduate level course that is also available for continuing professional development (CPD). Of the broad range of One Health research performed in ANZ, the majority is performed by teams with limited disciplinary diversity, although diversity is improving.
Summary: Progress has been made in building collaboration between human, animal, and environmental health professions. However, the lack of clearly defined competencies and agreed purpose for One Health may be impeding collaboration.

Keywords: *One Health*; *Australia*; *New Zealand*; *training*; *research*; *funding*; *zoonoses*; *Ecohealth*

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One Health is important in Australia and New Zealand (ANZ) because both countries have strong and diverse agricultural industries that required a period of rapid land use change, which has been associated with the emergence of zoonotic diseases (1). Australia, in particular, has very diverse and unique flora and fauna that inhabit ecological zones from high alpine to wet tropical. Indeed, a recent review identified at least eight new infectious diseases have emerged since 1973 as a result of land use change, such as Hendra virus, Australian Bat Lyssavirus, and a number of arboviruses (2).

Scientists from ANZ have contributed significantly to the development of One Health concept in the Asia Pacific region. However, there is limited evidence of the explicit incorporation of One Health into the policies and practices of their departments of health and agriculture. The single possible exception is the Australian National Strategy for Antimicrobial Resistance that was developed using One Health approaches in a multisectoral process and jointly released by the federal departments of Health and Agriculture (3).

This review was designed to provide a resource for people seeking information on One Health research and training in ANZ. The methodology limited the coverage of training activities to formal academic courses/degree programmes and multiday workshops that were likely to be available in the future. Short, *ad hoc* symposia and workshops that were associated with independent research groups and projects were excluded. The scope of the review of training was broadened to include training activities identified as 'EcoHealth' and 'ecosystems health', because these labels are often used interchangeably and the competencies are considered to be similar to those of One Health. The coverage of research activities was restricted to those described in published papers and funded projects that were performed in ANZ.

Methods

There is no fixed definition of 'One Health' that can be used to guide the selection of activities for inclusion in this review. The high-level criteria used for this review were designed to identify activities that address a public health

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issue involving interactions between people and animals directly and via the environment. This guides the selection of research and training that include two or more disciplines in animal, public, and environmental health. Training activities were also evaluated against published One Health competencies (4) and suggested curriculum elements (5).

Research articles were identified using a search on the PubMed database with the following searching strategy: ((‘australia’[MeSH Terms] OR ‘australia’[All Fields]) OR (‘new zealand’[MeSH Terms] OR (‘new’[All Fields] AND ‘zealand’[All Fields]) OR ‘new zealand’[All Fields])) AND ((‘One Health’[Journal] OR (‘one’[All Fields] AND ‘health’[All Fields]) OR ‘one health’[All Fields]) AND (‘zoonoses’[MeSH Terms] OR ‘zoonoses’[All Fields])). An additional limited search for articles on antimicrobial resistance was conducted using the name of the prominent authors in the field, and abstracts mentioning sampling from humans and animals were included. A further broader search was conducted to ensure major groups were not missed.

A further search for articles using the terms ‘Australia’ and ‘New Zealand’ was performed on the archives of four open access journals listed on the One Health Initiative website (www.onehealthinitiative.com/journals.php):

1) *Infection Ecology and Epidemiology the One Health Journal* (Sweden) (www.infectionecologyandepidemiology.net/index.php/iee)
2) *Veterinary Sciences* (Switzerland) (www.mdpi.com/journal/vetsci)
3) *International Journal of One Health* (India) (www.onehealthjournal.org/)
4) *One Health* (www.journals.elsevier.com/one-health)

Studies were included if they were performed in ANZ and where possible involved people from two or more disciplines from public, animal, and environmental health. This scope included broader fields such as ecology, sociology, and governance. Studies performed in other countries were excluded to avoid repetition with other reviews in this special issue.

An internet search was conducted using the term ‘One Health’, ‘Ecohealth’ or ‘ecosystem health’ and a combination of the terms, ‘training’, ‘workshop’, ‘course’, ‘unit’, and ‘programme’. The titles and preliminary content of each of the returned hits previewed on the first three pages of search results were reviewed and individual links followed to the source if they contained content likely to relate to a One Health training course. The review of results ceased once the hits became irrelevant or repetitive. In addition, a separate search was performed on each of the websites for the universities that host schools of Medicine, Public Health, and Veterinary Science using the terms ‘One Health’, ‘Ecohealth’, and ‘ecosystem health’ individually. A final search was conducted using the names of well-known scientists and individuals known to the authors who are active in the field of One Health.

Research funding for One Health projects was identified by searching the databases of successful grants awarded by the Australian Research Council (2001 to date) (6) and the National Health and Medical Council (2000 to date) (7). The databases were searched for projects containing the following keywords: ‘one health’, ‘zoonos*’, ‘antimicrobial’, ‘leptospir*’, ‘Hendra’, ‘nipah’, ‘salmonella’, ‘campylobacter’, ‘lyssavirus’, ‘coxiella’, and ‘H5N1’. The descriptions and keywords of each identified study were reviewed, and studies fitting the inclusion criteria described above were included.

Results

One Health research in Australia and New Zealand

In total, 80 publications were identified from research groups in ANZ of which half were published after 2012 (Fig. 1), comprising 43 primary research publications followed by review articles and commentaries on the need for One Health. Few, if any, of the publications described purposeful studies designed to address broader system-related issues using cross-sectoral approaches. The majority of studies primarily focused on one host species with inference regarding transmission to other hosts. The major areas covered included antimicrobial resistance, enteric pathogens (food/water-borne), bat-borne diseases, and enteric protozoa. Of the remainder, there were small foci of activity related to leptospirosis, Q fever, asthma, and issues associated with intersectoral collaboration and governance.

Only a selection of studies on antimicrobial resistance (AMR) is included in this review because this is a large and diverse topic that has largely been approached from a single sector point of view, i.e. hospital vs. livestock. In addition, few studies met the criteria used in this review (i.e. multisectoral approaches or involving human and animal hosts). The majority of these studies in Australia have been undertaken by a single research group led by Professor Darren Trott at the University of Adelaide (8–14). Of these studies, only a small number of co-authors are employed outside the animal health field, and the study design is largely restricted to work with samples collected from animals. In New Zealand, multidisciplinary studies have been conducted on pets as sources of AMR.

A significant number of studies have been performed on enteric pathogens in Australia and especially in New Zealand. These studies largely reflect research to understand the animal reservoirs for human infections with *Campylobacter* (15–20) and *Salmonella*, specifically following a prolonged outbreak in New Zealand (21). This large body of work has led to the identification

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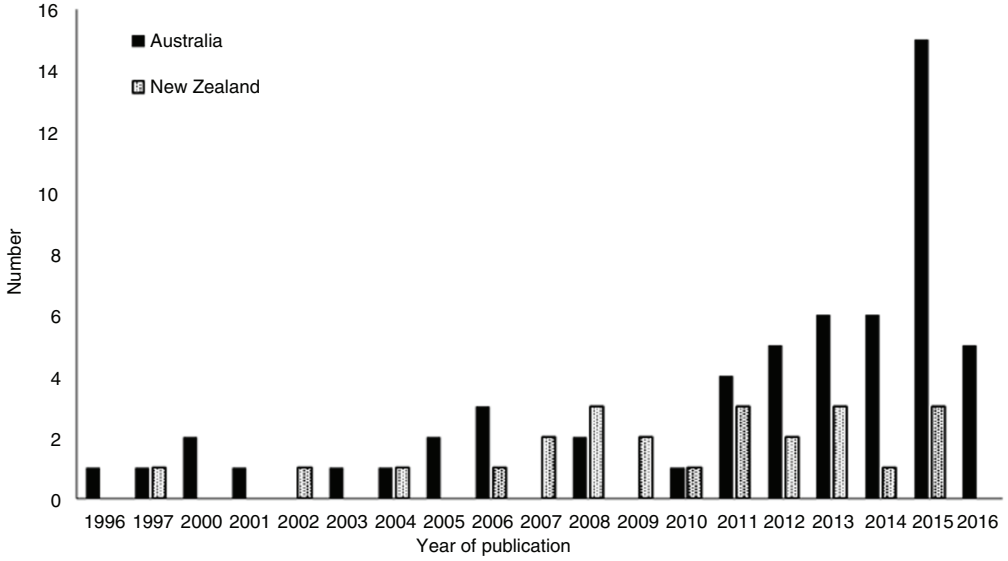

Fig. 1. Journal articles published on One Health topics by researchers in Australia and New Zealand.

of interventions to reduce exposure to *Campylobacter* risk (22) with a 54% decrease in human incidence and a 74% reduction in the number of cases attributed to poultry (23, 24).

Australia experienced two emerging infectious disease (EID) events in the past 10 years: Australian bat lyssavirus and Hendra virus (a henipavirus) (2). The subsequent research programme involved virological, ecological, and biomedical studies to characterise the virus and its reservoir host (25) and to identify therapeutic interventions such as a vaccine (26). The emergence of Hendra virus led to the formation of a local cross-sectoral committee comprising senior government officials from animal and human health as well as scientists from the fields of epidemiology, public health, and ecology (27). The committee responded to the crisis by advocating for funding to develop a vaccine for horses and initiating the development of improved infection control techniques in the veterinary and equine industries (27). As a result there has not been a single human case of Hendra virus since 2009 (28), and only a small number of infrequent cases in horses (29). The research on Hendra virus also allowed Australian scientists to contribute to research on the closely related Nipah virus that emerged in Malaysia and Bangladesh (30).

New Zealand has a large agricultural sector with 6.1 million dairy cattle and 29.1 million sheep (31). A significant programme of research on leptospirosis has been undertaken by Massey University that involves studies to determine exposure risk for people working with animals, such as veterinarians (32), and in meat processing industries (33). These studies are almost entirely performed by scientists from the Institute of Veterinary, Animal, and Biomedical Sciences (IVABS) with limited involvement of health professionals. However, the studies have been successfully able to identify factors associated with exposure of abattoir workers to *Leptospira* and potential solutions (33).

Eastern Australia is an area of high endemicity for Q fever (34). The majority of research in Australia tends to focus on analysis of notified cases (35), unusual outbreaks, (36, 37), or animal and environmental sources (38). However, a recent study by Bond et al. (39) demonstrated the application and outcomes of taking a One Health approach to an outbreak associated with a goat farm. The outbreak investigation and its management involved a team representing animal, environmental, and public health professionals. Activities included serological and molecular studies to characterise transmission followed by an evaluation of farming practices to identify points of intervention (39). An intensive human vaccination programme plus environmental and biosecurity interventions was credited with resolving the outbreak (39).

Research into farm-related exposures and the risk of asthma in people in New Zealand has been led by the Centre for Public Health Research at Massey University, with some collaboration of animal health scientists from the university (40, 41).

One Health training opportunities in Australia and New Zealand

In total, eight formal academic offerings and one standalone training workshop in One Health and EcoHealth were identified in ANZ (Table 1). They include two postgraduate degrees: the Master of Ecological Public Health (MEPH, University of Canberra (UCan)) and the

Table 1. Formal and informal training courses in One Health and Ecohealth available from academic institutions in Australia and New Zealand

Country	Institution	Type of training*	Course title/code	Web-link	Frequency
New Zealand	Massey University	Postgraduate degree	Master of Science (One Health)	www.massey.ac.nz/massey/learning/programme-course-paper/programme.cfm?prog_id=92431&major_code=2928	1-year (minimum) degree, annual enrolment on-campus and off-campus (online)
Australia	Murdoch University, School of Veterinary and Life Sciences	Undergraduate course	One Health (VET392) (previously Systemic Pathology, Toxicology and Chemotherapy)	www.handbook.murdoch.edu.au/units/details?unit=VET392	1 semester, offered annually on-campus only as part of DVM programme
Australia	Murdoch University, School of Veterinary and Life Sciences	Postgraduate course	One Health for Biodiversity Conservation (VET603)	www.handbook.murdoch.edu.au/units/details?unit=VET603	1 semester, offered annually on-campus and off-campus (online)
Australia	Murdoch University, School of Veterinary and Life Sciences	Postgraduate course	One Health Management and Leadership (VET655)	www.handbook.murdoch.edu.au/units/details?unit=VET655	1 semester, on-campus delivery as part of the Master of Health Policy and Leadership (MHPL)
Australia	University of Canberra	Postgraduate degree	Master of Ecological Public Health	www.canberra.edu.au/coursesandunits/course?course_cd=339JA&version_number=1&title=Master-of-Ecological-Public-Health&location=BRUCE&rank=CCC&faculty=Faculty-of-Health&year=2016	1.5 years (accelerated), entry two times per year on-campus and off-campus (online)
Australia	The University of Melbourne	Workshop	EcoHealth Solutions: Applying ecosystem approaches to health	www.onemda.unimelb.edu.au/ecohealth-solutions-applying-ecosystem-approaches-health-2-day-short-course	One-off 2-day workshop, on-campus (April 2016)
Australia	The University of Queensland	Undergraduate course	One Health: Animals, the Environment and Human Disease (VETS1030)	www.uq.edu.au/study/course.html?course_code=VETS1030	1 semester, Offered annually on-campus
Australia	The University of Queensland	Postgraduate course/ Workshop	One Health: Diseases at the Human-Animal interface (PUBH7031)	www.uq.edu.au/study/course.html?course_code=PUBH7031	Intensive 5-day course with assessment, offered annually on-campus

*Course = for credit towards a formal degree programme; Workshop = a short training programme of 1 day or more that does not earn credit towards a degree programme; postgraduate degree = a formal degree programme involving 1–2 years of full-time study.

Master of Science (One Health) (MSc (OH), Massey) offered in Australia and New Zealand, respectively. Two individual courses in One Health are offered as part of undergraduate degree programmes in Animal Science (University of Queensland (UQ)) and veterinary medicine (Murdoch University) and three courses in postgraduate master's degree programmes at UQ (1) and Murdoch University (2). There were limited opportunities for people not enrolled in academic degree programmes to access training. There was only one *ad hoc* short workshop in EcoHealth (University of Melbourne (UMelb)), and one of the postgraduate courses (UQ, PUBH7031) is available for non-enrolled participants as continuing professional development (CPD). Five of the eight courses/workshops are offered by veterinary schools, two by public health schools, and one by an indigenous health centre.

Each of the training activities identified in ANZ are based on different curricula and pedagogies depending on the disciplinary focus of the lead academic unit. The MSc (OH) is a specialisation of the MSc degree at Massey University, which is mainly consisted of courses on the principles of infectious disease epidemiology and control, with a focus on integrated multisectoral approaches to investigation and control of infectious diseases, and a tailored One Health research project. The MSc (OH) degree is designed and delivered by animal health and public health epidemiology and research centres at Massey University. The MEPH is offered by the Faculty of Health (UCan) and focuses on the ecological model of public health that emphasises the important interactions between the social, biological, economic, and environmental determinants of human health in an ecological framework. The curriculum is structured around the core disciplinary areas of public health, such as epidemiology, health promotion, and health economics, with an interdisciplinary emphasis and scope that extends beyond infectious and zoonotic diseases (i.e. One Health). Both degree programmes require the prior completion of an appropriate undergraduate degree.

The three units offered at Murdoch University require enrolment in specialised undergraduate and postgraduate degrees. The courses represent the shift from narrow disciplinary perspectives to encompass broader One Health approaches that emphasise recognition of the interrelatedness of animals, people, and their environment through a veterinary public health (VET392) and conservation medicine (VET603) frame. The one exception is VET655, which is an elective in the Master of Health Policy and Leadership. This multidisciplinary course would serve to extend the knowledge of health leaders to gain an understanding of the concept of cross-sectoral cooperation for improved management of public health threats at the human, animal, and ecosystem interface.

The undergraduate course offered at UQ (VETS1030) is taken as part of two degree programmes and introduces students to the concepts of One Health framed as the intersection between human medicine, veterinary/animal science, and ecosystems health. The UQ course PUBH7031 is an elective in the Master of Public Health, which is designed to provide students with instruction in the use of systems thinking to develop conceptual models and integrated intersectoral strategies to manage and prevent zoonotic diseases.

Massey University has also delivered interdisciplinary postgraduate One Health capacity-building programmes to three large cohorts of human health, animal health, and wildlife health professionals in Asia from 2010 to the present. This activity is supported by funding from the Avian and Human Influenza Fund, World Bank, and the European Union. A 'One Health Education into Action' approach is the signature feature of the Massey programme that is described in detail in a review of One Health in South Asia (42).

One Health research funding opportunities in Australia and New Zealand

A total of 21 grants to the value of A$18 million were awarded by the National Health and Medical Research Council (NHMRC) between 2000 and 2016. They included 4 individual fellowships, 14 project grants, and 3 Centres of Research Excellence (CREs). Only one project explicitly identified One Health in its title and description. This was a project aimed at examining existing EID legislation, identifying social and ethical barriers to effective EID risk governance, and creating a comprehensive statement of values to ensure the acceptability of One Health approaches to EID control to the Australian community. The remaining projects and fellowships focused on the development of vaccines for zoonotic diseases (cysticercosis/hydatids (6) and Hendra virus (2)) and research on animal/environmental reservoirs. Projects on pandemic influenza (H5N1) and Hendra virus were funded as part of two urgent calls for research to address these topics in 2006 and 2012, respectively.

Of the four CREs funded by the NHMRC with the potential to have One Health activities, only one is purposefully designed to adopt One Health approaches – 'The National Centre for Antimicrobial Stewardship: Using a One Health Approach' – that is hosted by the UMelb. The remaining three CREs are largely focused on research capacity to detect and respond to EID threats. The documented activities largely focus on research within the health sector with little information on cross-sectoral and One Health activity. They are the 'Australian Partnership for Preparedness Research on Infectious Disease Emergencies' hosted by the Peter Doherty Institute for Infection and Immunity (Doherty Institute) (43), the CRE in 'Protecting the Public from Emerging Infectious Diseases' hosted by the University of Sydney (44), and the 'NHMRC Centre for Research Excellence, Integrated

Systems for Epidemic Response' hosted by the University of New South Wales (45).

The Australian Research Council (ARC) provided funding for 15 grants worth a total of A$5.3 million since 2000, with 10 grants for A$4.2 million awarded in the past 5 years. All project grants and fellowships were for research on animal reservoirs of zoonoses conducted largely by groups representing either individual disciplines or a narrow disciplinary range (i.e. veterinary/biomedical science, ecology). Topics covered by these grants include modelling zoonotic parasites, wildlife dynamics, *Clostridium difficile* and antimicrobial resistance in food-producing animals, and risk factors associated with wild and companion animal populations.

The Australian Government's Cooperative Research Centre (CRC) Programme provided a 7-year grant (2003–2010) to establish the Australian Biosecurity CRC for Emerging Infectious Diseases (ABCRC). The ABCRC was a consortium of research organisations, livestock industry groups, and government agencies. Its key objectives were to protect Australia's public health, livestock, wildlife, and economic resources through research and education that strengthens the national capability to detect, diagnose, identify, monitor, assess, predict, and respond to EID threats which impact national and regional biosecurity (46).

Discussion

One Health research

The majority of research described in the included studies arose from teams representing a single sector, i.e. animal or public health. Few studies could be categorised as truly 'One Health' as a result of the lack of overt collaboration between individuals and institutions in different sectors. These were mainly published with a first author who was a health professional with animal and environmental health professionals in supporting roles. This agrees with the findings of a recent review of One Health research publications, which also showed that the veterinary and ecology research communities tended to work in isolation compared to a broader group of health-related researchers (47).

It was interesting to note that there appeared to be a larger number of studies that involved cross-sectoral and interdisciplinary research teams in New Zealand compared to Australia. This may be because of the smaller size of the country and the presence of a single veterinary school, which has a long track record in research on zoonotic disease. In addition, it was evident from the authorship of more recent studies that current research teams in both countries have become more interdisciplinary. One Health networks in New Zealand are also growing with the formation of One Health Aotearoa that was formed in 2013 as an alliance between the leading human and animal infectious disease researchers and research groups from University of Otago, Massey University, and the Institute for Environmental Science and Research. This alliance has led to joint symposia and workshops and increasing engagement with government agencies and policymakers.

Future research in the key areas identified in this review is likely to increasingly be multisectoral as a result of a growing number of informal One Health networks that are forming, largely around the needs of individual public health units in local departments of health. These networks and the publicity associated with them have increased the awareness of the benefits of One Health and collaboration across sectors that extends beyond research into training in areas such as large-scale outbreak response, which is common in livestock diseases but not for human disease. In addition, the formulation of the National AMR strategy is likely to trigger greater cross-sectoral collaboration to address the One Health challenges posed (3).

One Health training

This review focused on research and training activities that were conceptualised for, or applicable to, the study and control of public health issues at the human, animal, and environment interface, especially zoonotic diseases. The search for training activities was expanded to include those defined as EcoHealth and ecosystem health because they are considered by some to be interchangeable with One Health (48). Indeed, there is little difference in the descriptions of the core components of both the EcoHealth (49) and One Health approaches in terms of functional elements and thus pedagogical and curriculum requirements for training (4, 5).

The inclusion of the MEPH (UCan) highlights the blurring of the edges of each of the new fields of 'health' that have emerged. Advocates of ecological public health argue that current models of public health are no longer a sufficient means for understanding recent health challenges and that the alternative should be based on an ecological model (50). An ecological model draws on and integrates parts of other models and articulates modern thinking about complexity and system dynamics (51). This systems thinking methodology is considered a core competency of One Health (40) and one that is embraced in the UQ postgraduate course (PUBH7031). However, the explicit objectives of the MEPH relate to all adverse health states and not just those associated with animals and the environment.

All courses and workshops identified in this review are offered by academic institutions either alone or in collaboration with local government institutions. Although this provides continuity in terms of their availability, it limits access to training to those completing a degree programme. Only one course (PUBH7031) is offered each year in a format that allows people to attend if they

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do not wish to enrol in a degree programme (i.e. CPD). The 2-day workshop offered at the UMelb has a structure that suggests it is primarily designed as a training course, which increases the likelihood that it will be offered regularly, especially if it becomes part of a postgraduate degree programme.

The majority of courses that provide credit towards a degree are offered within undergraduate and postgraduate degrees in veterinary schools. There was only one degree programme and one intensive course offered by academic units in health faculties. This presents a challenge for the development of One Health approaches in practice because it shows that training is largely presented within restricted disciplinary boundaries. A similar observation was made by Mor et al. (5) who mapped the curriculum assets for One Health at Tufts University. Their study showed that the integration of assets across disciplines and the understanding of how this integration should occur were hampered by the lack of a well-defined set of desired competencies (5). However, the type and the level of training a person requires will depend on his or her previous tertiary education. For example, it is highly likely that a Master of Public Health will provide a veterinarian with the necessary training to work in a One Health team because the degree will complement his or her existing training by providing knowledge of the public health systems and paradigms. A degree such as the MSc (OH) may be one of the few opportunities for a health professional to obtain formal training to equip himself or herself to work and understand the animal health paradigm.

Observed gaps

The most obvious gap in One Health research and training is the lack of obvious integration and collaboration across the human health, animal health, and ecology/wildlife sectors. This has been observed in a global review of One Health research (46). It is particularly obvious in major government funding initiatives for EIDs where the centres are hosted by a medical school and include investigators drawn from similar academic units. There is limited engagement with wildlife and veterinary scientists and no apparent engagement with social scientists, economists, and environmental health scientists.

Funding for One Health research in Australia is problematic because the two major funding sources have separate mandates and funding priorities. The ARC's policy on health and medical research states that it will not normally fund health and medical research, and the NHMRC will only fund medical and public health research. This leaves a conceptual gap that limits the ability of multidisciplinary teams to work across the human–animal–ecosystem interface. This is evidenced by the lack of disciplinary diversity in the NHMRC CREs on emerging diseases and antimicrobial resistance, which are largely medically focused.

One potential solution would be for the two organisations to agree on a mechanism for cross-sectoral funding. However, achievement of this change will require careful study and documentation of successful One Health case studies in Australia that clearly demonstrate cost-effective approaches that provide significant public and animal health benefits.

Conflict of interest and funding

SAR is an employee of and SMW is a student at the University of Queensland. SAR coordinates and delivers PUBH7031 and provides instruction into VETS1030. JM is an employee of Massey University and coordinates aspects of the MSc (One Health). SW has no competing interests.

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