Risk of feline immunodeficiency virus (FIV) infection in pet cats in Australia is higher in areas of lower socioeconomic status

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Abstract

Feline immunodeficiency virus (FIV), feline calicivirus (FCV) and feline herpesvirus (FHV-1) are common viral infections of domestic cats in Australia. A retrospective cross-sectional study was performed to investigate the possible effect of area-based socioeconomic factors on the occurrence of FIV, FCV and FHV-1 infection in Australian client-owned cats. A total of 1,044 cases, entered onto a voluntary Australian online disease surveillance system between July 2002 and June 2017, were analysed with respect to their postcode-related socioeconomic factors using the Socio-Economic Indexes For Areas (SEIFA). SEIFA consists of four different indexes which focus on different aspects of socioeconomic advantage and disadvantage. A retrospective space-time cluster analysis was also performed for each disease and epicentre postcodes were analysed against the four SEIFA indexes. Signalment details including age, sex, neuter status and breed were also considered. A significant correlation was observed between areas of lower socioeconomic status and a higher number of logged cases of FIV infection for all four SEIFA indexes (P = 0.0002). Postcodes with SEIFA indexes below the Australian median ('disadvantaged' areas) were 1.6-2.3 times more likely to have reported cases of FIV infection than postcodes with SEIFA indexes above the median ('advantaged' areas). In contrast, no correlation was observed between the number of logged cases of FCV or FHV-1 infection and any of the four SEIFA indexes (P > 0.05). When postcodes from clusters of FIV, FCV and FHV-1 cases were compared to non-cluster postcodes, a significant

correlation was identified between clusters of infection and higher SEIFA scores for three of the four SEIFA indexes ($P > 0.05$), suggesting disease outbreaks for all three infections occurred in areas of socioeconomic advantage. When signalment data were analysed for the three infections, FIV-infected cats were more likely to be older ($P < 0.00001$), male ($P < 0.0001$), neutered ($P = 0.025$) and non-pedigree ($P < 0.0001$) than FCV and FHV-1 infected cats. Results from this study suggest that area-based disease control strategies may be effective to reduce the prevalence of FIV infection in pet cats in Australia.

1. Introduction

There are currently an estimated 3.3 million pet cats (*Felis sylvestris catus*) in Australia, with 29% of Australian households owning at least one cat [1-3]. Feline immunodeficiency virus (FIV), feline calicivirus (FCV) and feline herpesvirus (FHV-1) are common infections of the domestic cat, both in Australia and overseas, and are major causes of feline morbidity despite the availability of reasonably efficacious vaccines [4,5].

A total of 14.5 million domestic cats and 19 million feral cats worldwide are thought to be infected with FIV [6]. Transmission of FIV is primarily through cat bite wounds, meaning prevalence is higher where aggression and overcrowding are present, in particular stray and feral cat populations [7,8]. In Australia, FIV seroprevalence was reported to be 21 and 25% in two separate feral cat populations and 8% in the general pet population, while in Canada, FIV seroprevalence was found to be 23% in urban strays and 6% in client owned cats [9,10]. The disparity in infections rates between the different groups of cats in these studies suggests a possible role for stray and feral cats as reservoirs of FIV in both countries. Another Australian study reported that 80% of client-owned cats had at least some outdoor access, suggesting likely exposure to stray and feral cats and therefore FIV infection [3]. Other risk factors identified for FIV infection, apart from lifestyle (i.e. outdoor access and fighting), include increased age (since infection is lifelong and therefore risk of infection is cumulative), sex (male), neuter status (entire) and possibly vaccination status (FIV-unvaccinated) [4,9,11-16].

Some studies have found a higher rate of FIV infection in cats classified by veterinarians as clinically ‘unwell’ or ‘sick’, most likely due to the virus’ predilection for cells of the immune system and subsequent resulting immunosuppression, therefore increasing the risk of opportunistic infections [11,17,18]. Common sequelae of FIV infection include gingivitis, upper respiratory tract infections, toxoplasmosis and lymphosarcoma [19-21].

FCV and FHV-1 infection are recognised as major causes of feline upper respiratory tract disease (FURTD), negatively impacting on feline welfare and quality of life [22-24]. FCV and FHV-1 are frequently detected in sick cats in Australia; studies have reported prevalences of 10-16% for FCV, and 7-21% for FHV-1, in cats presenting with FURTD [25-27]. A study of client-owned cats in the US, using a convenience sample of healthy and sick cats combined (i.e. a heterogenous population), reported prevalences of 26% for FCV and 5% for FHV-1, respectively [28]. FURTD is a major cause of euthanasia in shelters, second only to overcrowding [29], and stress, overcrowding and close contact are important factors in the transmission of both viruses [30-32]. One study of eight shelters in the US demonstrated a high variability in prevalence of FCV and FHV-1 infection between shelters studied [29]. In heterogenous shelter populations in Europe and North America, rates of 33-37% for FCV and 11-20% for FHV-1 have been reported [33,34]. Other known risk factors for FCV and FHV-1 infection include age (kittens and juveniles), sex (male), vaccination status (unvaccinated) and lifestyle (outdoor access and multi-cat households) [28,35]. Due to the viruses’ tropism for upper respiratory and conjunctival epithelium, FCV and FHV-1 infected cats typically present with clinical signs such as conjunctivitis, nasal discharge, corneal ulceration and rhinotracheitis [22,30-32,36].

It is widely accepted that humans living in areas of lower socioeconomic status have higher health risks, including infection with human immunodeficiency virus (HIV-1) and human herpesvirus [37,38]. Similarly, a study of canine parvovirus (CPV) in client-owned dogs in Australia reported a correlation between areas of socioeconomic disadvantage and clusters of CPV infection [39]. To our knowledge, no investigation into a possible relationship between

the socioeconomic status of cat owners and feline health has been performed to date. The aim of the current study, therefore, was to determine if there was an association between the area-based socioeconomic status of cat owners and risk of FIV, FCV or FHV-1 infection in the pet cat population in Australia.

2. Methods

2.1. Study population

All logged cases of FIV, FCV and FHV-1 infection were retrieved from the Disease WatchDog database (formerly owned by Virbac Animal Health, Australia, now owned by the VetCompass Australia consortium [40]). This disease surveillance system, active between June 2002 and July 2017, relied on veterinary clinics to voluntarily register online and submit cases of common canine and feline infections.

Extracted cases were screened for duplicates based on patient name and clinic, with the earliest record of the case retained for analysis and the later record excluded. Cases concurrently diagnosed with more than one of the three infections were duplicated and one infection was re-labelled as the secondary disease, ensuring that all disease cases were included in the data analysis but only accounted for once. Details available for each case included patient name, age (years, months and weeks), sex (male or female), neuter status (neutered, entire or unknown), breed (pedigree or non-pedigree), primary disease, date of diagnosis, method of diagnosis, vaccination status (vaccinated, unvaccinated or unknown), and owner postcode. Cases of FIV infection were diagnosed by antibody detection using a rapid in-clinic test (any commercially available brand of test kit) or by polymerase chain reaction (PCR) testing at an external laboratory (IDEXX Laboratories, East Brisbane, Queensland, Australia; or Gribbles Veterinary Pathology, Glenside, South Australia, Australia). Cases of FCV and FHV-1 infection were diagnosed by clinical presentation or by PCR testing at an external laboratory (IDEXX Laboratories, East Brisbane, Queensland, Australia).

2.2. Assessment of area-based socioeconomic status

Socioeconomic data from the 2016 Australian Census was collected by the Australian Bureau of Statistics (ABS) and used by the Australian Government to develop the Socio-Economic Indexes For Areas (SEIFA). SEIFA is a useful tool for interpreting area-based socioeconomic factors and consists of four indexes which focus on different aspects of advantage and disadvantage. The indexes are developed in different ways and combine aspects including income, education, employment, occupation and housing variables [41].

The Index of Relative Socioeconomic Advantage and Disadvantage (IRSAD) examines a range of factors that relate to an individual's social advantage or disadvantage, including education, employment, occupation, housing, language, disability and other factors. The Index of Relative Socioeconomic Disadvantage (IRSD) is similar to the IRSAD except the IRSD only examines disadvantageous factors, not those of advantage. The Index of Economic Resources (IER) examines factors relating to financial advantage and disadvantage, including high or low income, rent and other factors. The Index of Education and Occupation (IEO) examines factors relating to social advantage or disadvantage relating to employment and education [41].

The ABS used the Census data to give all Australian postcodes a ranked score for IRSAD, IRSD, IER, and IEO from 1 to 10, with 1 representing the most socioeconomically disadvantaged areas and 10 representing the least disadvantaged (i.e. most advantaged) areas. Using this information, cases in the current study of FIV, FCV and FHV-1 infection were assigned four SEIFA scores by the primary author (VT) based on the recorded owner postcode.

2.3. Data analysis

Chi-squared tests of independence were performed to analyse case signalment (sex, neuter status and breed) within each infection group (i.e. FIV, FCV and FHV-1), and between infection groups, using Statistix version 8.0 (Tallahassee, FL, USA). Statistix was also used to perform

Kruskal-Wallis one-way analysis of variance (AOV) testing to compare median ages between the different disease populations. This study did not have a control population, hence there was an expected equal distribution within each binary variable for each disease.

A Spearman's Rank Correlation test was performed on SEIFA indexes within each infection group (i.e. FIV, FCV and FHV-1) to measure the strength and association between the two ranked variables (i.e. SEIFA values and number of cases of each infection). Kruskal-Wallis one-way AOV testing was used to compare 'disadvantaged' socioeconomic areas (SEIFA indexes below the Australian median score) and 'advantaged' socioeconomic areas (SEIFA indexes above the Australian median score) with respect to incidence of each disease. Odds ratios were calculated testing by using 2x2 contingency tables and results from Kruskal-Wallis one-way AOV testing.

Cases of FIV, FCV and FHV-1 infection were mapped using ArcGIS version 10 (ERSI Redmond, WA, USA). A retrospective space-time analysis scanning for clusters with high rates of disease was performed using SaTScan version 9.4.1 (Boston, MA, USA). Clusters of FIV, FCV and FHV-1 infection were identified using a maximum special cluster size of 5% of the population at risk and a maximum temporal cluster size of 90 days within the study period. A Wilcoxon rank sum test was performed to compare SEIFA scores of postcodes within a reported cluster and postcodes outside of clusters using Statistix.

For all analyses, statistical significance was considered at $P < 0.05$.

3. Results

3.1. Study population

Extraction of logged cases of FIV, FCV and FHV-1 infection from Disease WatchDog yielded 1,077 cases from 287 postcodes and 145 veterinary clinics. In total, 37 duplicate case records were removed, and of the remaining cases, two cats were concurrently infected with FHV-1 and FIV, and two cats were concurrently infected with FCV and FHV-1, yielding a final total of

1,044 cases for data analysis. FHV-1 was the most commonly reported infection (607/1,044, 58%), followed by FCV (256/1,044, 25%), and FIV (181/1,044, 17%).

Signalment data for each infection is summarised in Table 1. Considering only cases with sex recorded (749/1,044, 72%), males were more common than females (461 *versus* 288, respectively). Of cases with a recorded neuter status (749/1,044, 72%), neutered cats were more common than entire cats (490 *versus* 259, respectively). Of cases with a recorded breed (756/1,044, 72%), non-pedigree cats were more common than pedigree cats (585 *versus* 171, respectively).

FIV infection was most commonly diagnosed by antibody detection (88%), followed by PCR testing (12%). FCV and FHV-1 infection were most commonly diagnosed by clinical presentation (92% and 98%, respectively), followed by PCR testing (8% and 2%, respectively; Table 2).

In total, 287 postcodes were reported across Australia, comprising New South Wales (56%), Queensland (16%), Victoria (13%), South Australia (6%), Western Australia (5%), Tasmania (3%), Northern Territory (0.1%) and Australian Capital Territory (0.001%). Mapping of cases for each infection is shown in Figure 1.

3.2. Intragroup analysis

Males were overrepresented in cases of FIV and FCV infection ($P < 0.0001$ and $P = 0.043$, respectively; Chi-squared tests of independence; Table 1). There were significantly more neutered cats than entire cats for FIV, FCV and FHV-1 infection ($P < 0.0001$ for FIV and FHV-1 infection, $P = 0.032$ for FCV infection; Chi-squared tests of independence), and non-pedigree cases were overrepresented in all three groups ($P < 0.0001$; Chi-squared tests of independence; Table 1).

3.3. Intergroup analysis

When comparing signalment between groups, FIV-infected animals were significantly older than cats with FCV or FHV-1 infection ($P < 0.00001$; Kruskal-Wallis one-way AOV test). Cats with FIV infection had the highest reported median age of 74 months, while cats with FCV or FHV-1 infection had a median age of 12 months and 16 months, respectively (Table 1).

There were significantly more cases of FIV-infected males compared to FCV and FHV-1 infected males (82% *versus* 57% *versus* 53%; $P < 0.0001$; Chi-squared tests of independence; Table 1). There was also a significant difference in neuter status and breed between groups, with significantly more neutered and non-pedigree cats reported with FIV infection compared to FCV or FHV-1 infection ($P = 0.025$ and $P < 0.0001$, respectively; Chi-squared tests of independence; Table 1).

3.4. Risk factor analysis

There was a significant negative correlation between FIV infection and all four SEIFA indexes, i.e. there was a higher number of FIV cases reported in postcodes with relatively lower SEIFA indexes ($P = 0.0002$; Spearman's Rank Correlation tests; Table 3). Disadvantaged areas were 1.6-2.3 times more likely to have reported cases of FIV infection than advantaged areas (IRSAD 2.3 times, IRSD 2.3 times, IER 1.8 times and IEO 1.6 times; $P = 0.0001$; Kruskal-Wallis one-Way AOV tests; Figure 2 and Table 4).

There was no association between FCV or FHV-1 infection and any of the four SEIFA indexes ($P > 0.05$; Spearman's Rank Correlation tests; Table 3), nor any difference when disadvantaged and advantaged areas were compared ($P > 0.05$; Kruskal-Wallis one-way AOV tests; Table 4).

3.5 Cluster analysis

There were seven, two and eleven space-time disease clusters of FIV, FCV and FHV-1 cases identified, respectively. Cluster details are described in Table 5.

When median scores of SEIFA indexes for clustered and non-clustered postcodes were compared, a significant difference was observed for three of the four SEIFA indexes for FIV and FCV infection, and all four SEIFA indexes for FHV-1 infection ($P < 0.0001$; Wilcoxon Rank Sum test; Table 6). In all analyses, the median SEIFA score was higher for clusters than for non-clusters, suggesting disease outbreaks occurred in areas of socioeconomic advantage.

4. Discussion

Cats with FIV infection were 1.6-2.3 times more likely to reside in disadvantaged areas (socioeconomic scores lower than the median) than advantaged areas, demonstrating for the first time a clear correlation between socioeconomic status and feline health in Australia. Comparable findings have been reported in dogs in Australia, with clusters of CPV cases more likely to occur in areas of greater relative socioeconomic disadvantage [39], and dogs in communities with lower economic status more likely to be infected with zoonotic pathogens, parasites and canine distemper virus [42]. Elsewhere, other studies have reported correlations between relative lower income and education with obesity, as well as reduced knowledge of pet healthcare and reduced inclination to spend money on pet health [43-46]. Recently, a global study of FIV prevalence rates reported an decreasing rate of FIV infection with increasing national income, suggesting a possible causal relationship between the investment in animal control programs, size of the feral cat and cat colony populations and subsequent impact on FIV prevalence [47]. Despite the currently available FIV vaccine (Fel-O-Vax FIV®, Boehringer Animal Health, Australia) only having a published protective rate of 56% [4], it is also possible that a lower vaccine uptake in disadvantaged areas of Australia compared to advantaged areas may have contributed to the higher number of FIV cases reported in these areas in the current study. Whether vaccination rate plays a role in case clustering is unknown since companion animal vaccination rates by geographic area is currently not reported or published. Regardless, this finding suggests that consideration needs to be given to providing FIV vaccination as a part of community pet health programs, particularly when FIV ‘outbreaks’ are suspected by local veterinarians.

In contrast to FIV infection, no correlation was observed between cases of FCV and FHV-1 infection and owner socioeconomic status. This difference may be due to vigilant vaccination against these diseases in Australia, as recommended in the World Small Animal Veterinary Association and Australian Veterinary Association vaccination guidelines [48,49]. Vaccination rates in Australia for FCV and FHV-1 are likely very high, with a survey of Australian and New Zealand pet owners reporting that 88% believed regular vaccinations were necessary [2].

There was evidence of case clustering for FIV, FCV and FHV-1 infection in socioeconomically advantaged areas. This finding may have been a reporting phenomenon, due to a higher concentration of clinics registered with Disease WatchDog in urban areas, which are generally associated with higher SEIFA scores compared to all postcodes throughout Australia. In addition, with regards to FCV and FHV-1 infection, the major causes of FURTD, the observed association between disease clustering and socioeconomic advantage may have reflected risk factors related to the behaviour of higher socioeconomically ranked owners. For example, cat owners who were more likely to board their cats in a cattery during holiday periods, with resulting increased exposure to FURTD, and/or reactivation of latent FHV-1 virus due to boarding-associated stress.

Age (older cats) was found to correlate with increased risk of FIV infection, presumably due to the lifelong nature of infection. Non-pedigree and neutered cats were overrepresented with FIV, FCV and FHV-1 infection, likely due to a sampling bias. One study of pet cats in Australia and New Zealand reported that 72% were non-pedigree cats and 94% were neutered [2]. Male cats were at increased risk of FIV and FCV infection, but not FHV-1 infection. It is well known that male cats are at higher risk of FIV infection due to increased territorial behaviour and fighting [7,11]. The explanation for the FCV and FHV-1 findings is unknown, especially since a previous Australian study found male cats were at increased risk of FHV-1 (but not FCV) infection [50].

The main constraint of the current study was the source of the sample population. Due to the voluntary nature of clinical case submissions by veterinarians, the total number of cases of each infection in Australia could not be estimated, and it is possible that the cases extracted and analysed were not a representative sample for the period selected. At the time of Disease WatchDog closing, approximately 10% of clinics were registered with Disease WatchDog and submitting cases (Dr. Mark Kelman, *per comms*). Furthermore, this small pool of clinics entering cases onto the database may have not been representative of veterinary clientele in Australia and possibly skewed the SEIFA scores, and may have been responsible for a false FIV cluster (Cluster 2) owing to a single submission from a clinic. Another limitation of the study was a lack of identification in the Disease WatchDog data as to the ownership status of the cat (e.g. whether the cat was privately owned, residing a shelter or feral). It was assumed that most cases were owned cats due to private veterinary clinics submitting cases, thereby creating a bias towards owned cats and away from stray and feral cats. Some clinics, however, could have been performing shelter work or treating stray cats, and it would be useful in future studies to record the ownership status of the cat to enable reporting of the frequency of each infection in different cat populations.

5. Conclusion

The results of area-based risk factor analysis demonstrated an association between cases of FIV infection and socioeconomic disadvantage in Australia, possibly highlighting the role that income and education play in providing well-informed health care for pet owners. Area-targeted FIV vaccination and education programs may reduce the incidence of FIV-associated disease, and there is an urgent need to develop a more efficacious FIV vaccine. The contagious nature of FIV, FCV and FHV-1 infection can cause clusters of disease in time and geographical space, and in the current study case clustering for each infection occurred in socioeconomically advantaged areas in Australia. Timely identification of clusters may lead to the development of targeted disease prevention strategies and permit further investigation into why case clusters occur.

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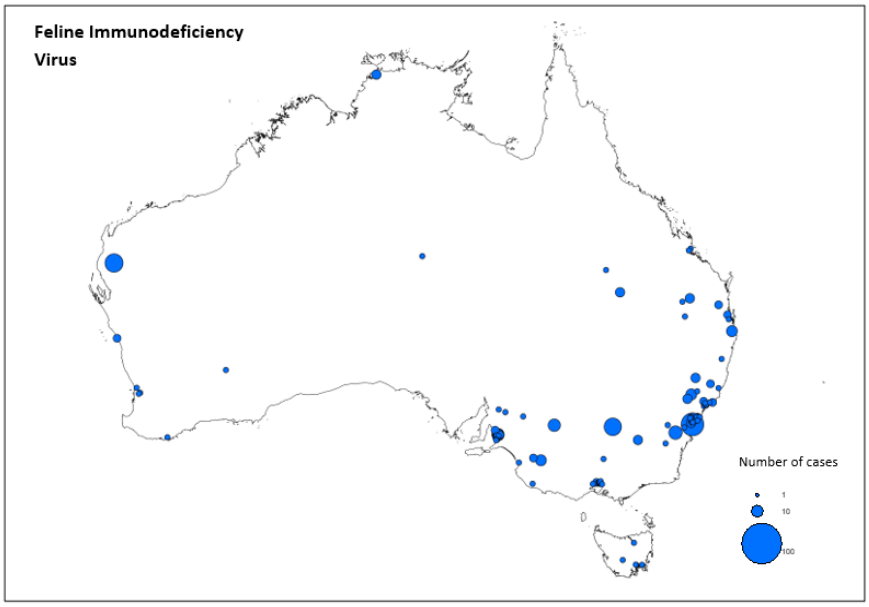
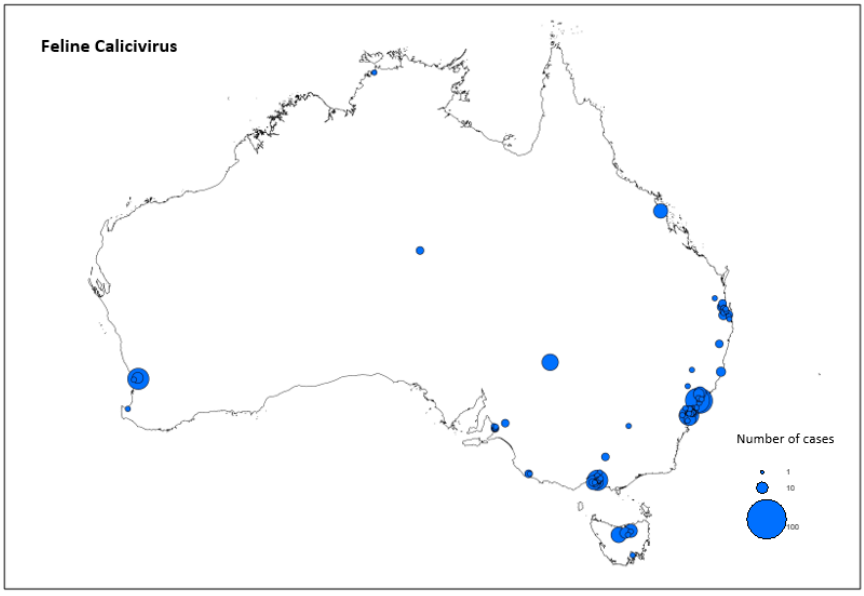
Figures and Tables

Figure 1: Map of reported cases of FIV, FCV and FHV-1 infection in Australia from Disease WatchDog (2002 - 2017). Mapped using ArcGIS version 10, ERSI Redmond, WA, USA.

a)


Feline Immunodeficiency
Virus
Number of cases
1
10
100

b)


Feline Calicivirus
Number of cases
1
10
100

c)

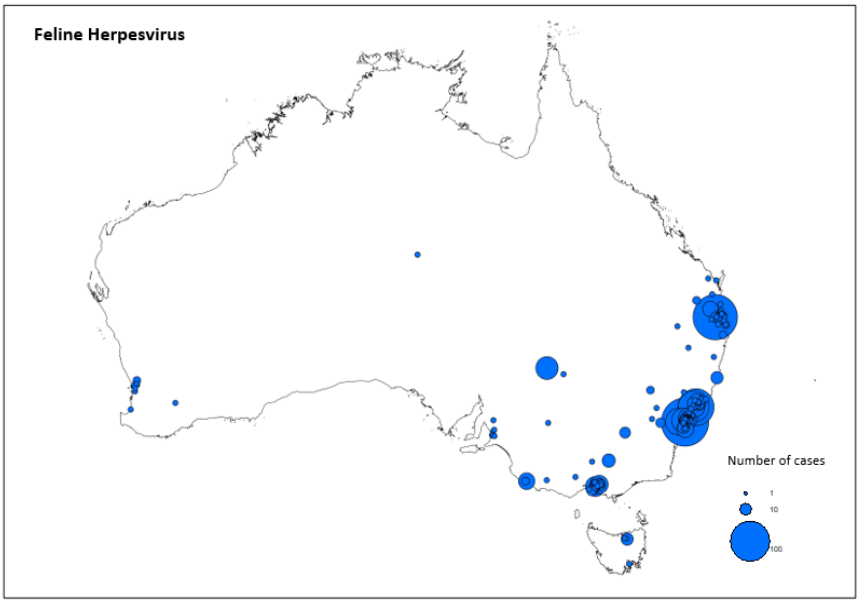
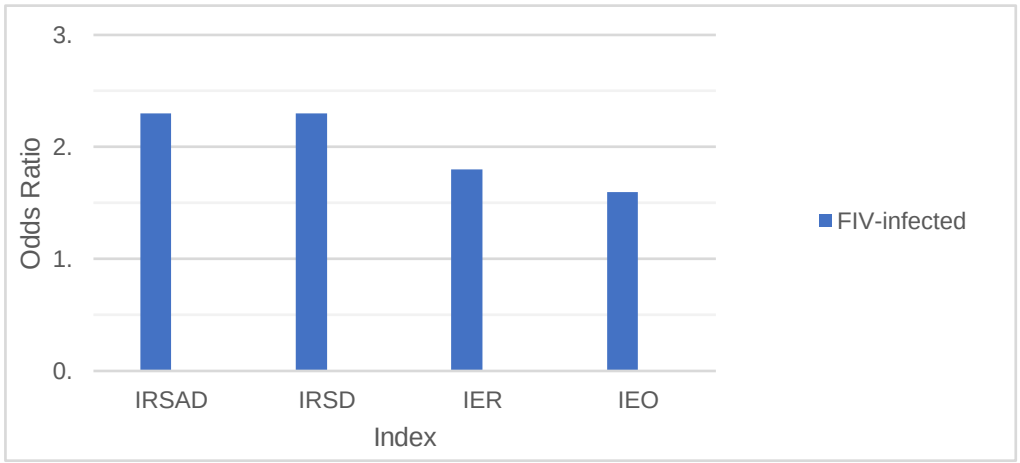


Figure 2: Odds ratios for cases of FIV infection based on socioeconomic status, calculated by comparing FIV disease incidence for disadvantaged socioeconomic areas (SEIFA scores below the Australian median score) and advantaged socioeconomic areas (SEIFA scores above the Australian median score). Disadvantaged areas were 1.6-2.3 times more likely to have reported cases of FIV infection than advantaged areas ($P < 0.0001$).



IRSAD = The Index of Relative Socioeconomic Advantage and Disadvantage
IRSD = The Index of Relative Socioeconomic Disadvantage
IER = The Index of Economic Resources
IEO = The Index of Education and Occupation

Table 1: Signalment data for logged cases of FIV, FCV and FHV-1 infection across Australia, extracted from Disease WatchDog (2002 - 2017). Results from Chi-squared independence testing within each infection group (intragroup analysis) are displayed in brackets. Results from chi-squared independence testing comparing infection groups (intergroup analysis) are displayed in the text.

Disease	No. of cases	Median age and range	Sex distribution (M vs F)	Neutering status (entire vs neutered)	Breed (pedigree vs non-pedigree)
FIV	181	74 months (5 - 204)	82% *vs* 18% (*P* < 0.0001)	28.5% *vs* 71.5% (*P* < 0.0001)	5.5% *vs* 94.5% (*P* < 0.0001)
FCV	256	12 months (0.25 - 216)	57% *vs* 43% (*P* = 0.043)	41.5% *vs* 58.5% (*P* = 0.32)	33% *vs* 67% (*P* < 0.0001)
FHV-1	607	16 months (0.5-240)	53% *vs* 47% (*P* = 0.19)	33.5% *vs* 66.5% (*P* < 0.0001)	25% *vs* 75% (*P* < 0.0001)

Table 2: Methods of diagnosis for logged cases of FIV, FCV and FHV-1 infection, extracted from Disease WatchDog. The method of diagnosis was not recorded for 13 cases (7 cases of FIV infection, 5 cases of FCV infection and 1 case of FHV-1 infection).

Disease	Method of diagnosis			Total
	Clinical presentation	In-house antibody testing	PCR testing	
FIV	NA	153	21	174
FCV	230	NA	21	251
FHV-1	592	NA	14	606
Total	824	153	56	1031

NA = not applicable
PCR = polymerase chain reaction

Table 3: Comparison of number of FIV, FCV and FHV-1 reported infections and postcode SEIFA indexes ranked 1 to 10, using Spearman's Rank Correlation. A negative number indicates negative correlation, i.e. there were fewer cases reported as the SEIFA index rank increased (more advantaged). A positive number indicates positive correlation, i.e. there were more cases reported from areas with higher SEIFA indexes. Significant correlations ($P < 0.05$) are shown in bold.

	IRSAD	*P* value	IRSD	*P* value	IER	*P* value	IEO	*P* value
FIV	-0.0740	**0.0002**	-0.0777	**0.0001**	-0.0847	**< 0.0001**	-0.0826	**< 0.0001**
FCV	-0.0069	0.73	-0.0169	0.40	-0.0187	-0.35	-0.0173	0.39
FHV-1	0.0174	0.39	0.0012	0.95	-0.0232	0.35	-0.0056	0.78

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Table 4: Comparison of case incidence for FIV, FCV and FHV-1 infections between 'disadvantaged' areas (SEIFA index less than the Australian median score) and advantaged areas (SEIFA index more than the Australian median score), using Kruskal-Wallis one-way analysis of variance testing. Significant correlations ($P < 0.05$) are shown in bold.

	IRSAD	*P* value	IRSD	*P* value	IER	*P* value	IEO	*P* value
FIV	14.77	**0.0001**	20.21	**< 0.0001**	14.78	**0.0001**	18.21	**< 0.0001**
FCV	0.12	0.73	0.91	0.34	0.55	0.46	1.94	0.16
FHV-1	0.79	0.37	0.01	0.91	0.63	0.43	0.17	0.68

Table 5: Clusters of FIV, FCV and FHV-1 infection in Australia identified using space-time permutation modeling from cases reported in Disease WatchDog from July 2002 to June 2017.

Cluster no.	Start date	End date	Cluster length	Radius (km)	No. cases per cluster	Observed/expected cases ratio	Epicentre postcode	Epicentre suburb
FIV								
1	20/05/2013	31/05/2013	11	0	5	17.07	5107	Green Fields, SA
2	10/07/2013	10/07/2013	0	17.2	6	20.33	3205	South Melbourne, VIC
3	3/10/2013	12/10/2013	9	10.3	5	20.33	2560	Campbelltown, NSW
4	20/02/2014	18/03/2014	26	164.1	3	61.00	5440	Manna Hill, SA
5	7/07/2014	14/08/2014	38	123.4	5	16.34	2848	Clandulla, NSW
6	22/04/2013	29/04/2013	7	29.46	4	24.13	5371	Roseworthy, SA
7	15/01/2013	04/03/2013	48	155.78	5	14.37	4404	Formartin, QLD
FCV								
1	5/11/2009	17/01/2010	73	11.4	8	17.07	2047	Drummoyne, NSW
2	14/06/2013	10/07/2013	26	11.3	4	51.20	4124	New Beith, QLD

FHV-1								
1	8/01/2010	22/03/2010	73	0	5	12.46	2119	Beecroft, NSW
2	25/07/2014	17/10/2014	84	17.2	6	21.68	5275	Taratap, SA
3	21/03/2011	4/06/2011	75	10.3	5	86.71	2130	Summer Hill, NSW
4	1/06/2010	29/06/2010	28	164.1	3	22.76	2213	Panania, NSW
5	13/06/2012	9/08/2012	57	123.4	5	10.18	4208	Norwell, QLD
6	6/11/2013	2/01/2014	57	29.5	4	18.27	3978	Clyde, VIC
7	13/09/2010	23/09/2010	10	0	4	17.68	3223	Portarlington, VIC
8	26/11/2010	3/02/2011	69	155.8	5	48.17	7255	Flinders Island, TAS
9	5/06/2013	7/06/2013	2	87.4	3	46.69	3199	Frankston, VIC
10	19/05/2014	23/05/2014	4	81.7	3	35.71	2880	Packsaddle, NSW
11	9/08/2010	23/10/2010	75	0	2	14.75	2578	Bundanoon, NSW

Table 6: Wilcoxon Rank Sum test mean ranks on disease cluster and non-cluster postcodes identified using space-time permutation modeling from cases reported in Disease WatchDog from July 2002 to June 2017. Significant correlations ($P < 0.05$) are shown in bold.

	IRSAD			IRSD			IER			IEO		
	Non-cluster	**Cluster**	***P* value**	**Non-cluster**	**Cluster**	***P* value**	**Non-cluster**	**Cluster**	***P* value**	**Non-cluster**	**Cluster**	***P* value**
FIV	1211.5	1582.9	**< 0.0001**	1216.5	1525.0	**< 0.0001**	1248.6	1153.4	0.072	1198.7	1737.4	**< 0.0001**
FCV	1213.8	1915.6	**< 0.0001**	1220.7	1745.0	**< 0.0001**	1241.5	1228.0	0.86	1207.6	2084.5	**< 0.0001**
FHV-1	1203.8	1455.9	**< 0.0001**	1205.3	1447.1	**< 0.0001**	1215.5	1388.1	**< 0.0001**	1205.9	1446.8	**< 0.0001**

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