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PATHOGENS OF HOUSE MICE ON ARID BOULLANGER ISLAND AND SUBANTARCTIC MACQUARIE ISLAND, AUSTRALIA

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ABSTRACT: Studies on island populations of house mice (*Mus domesticus*) and their viruses reveal insights into viral persistence in isolated communities. We surveyed the ectoparasites, endoparasites, and antiviral antibodies for 11 murine viruses and two bacteria of house mice inhabiting two islands off Australia. House mice on Boullanger Island were seropositive to two viruses, murine cytomegalovirus and epizootic diarrhea of infant mice. On subantarctic Macquarie Island, house mice were seropositive for five viruses: murine cytomegalovirus, lymphocytic choriomeningitis virus, mouse parvovirus, epizootic diarrhea of infant mice, and Theiler's murine encephalomyelitis virus. The diversity of antiviral antibodies was lower among populations of house mice on islands than those inhabiting mainland Australia. The decreased diversity of viruses in island populations of house mice may be a function of which agent the founder mice transfer to the island and related to the low densities which the host population may periodically reach over time.

Key words: ELISA, house mouse, islands, murine cytomegalovirus, *Mus domesticus*, parasites, pathogens, serologic survey.

INTRODUCTION

House mice (*Mus domesticus* or *Mus musculus*) adapt well to a variety of island ecosystems worldwide (e.g., Berry and Jakobson, 1975; Chown and Smith, 1993). Information on parasites infecting mainland house mice is reviewed by Tattersall et al. (1994), however, complementary parasite information for island house mice is sparse (Moro et al., 1999; Pisanu et al., 2001).

Island populations may harbor fewer pathogens than non-island populations by virtue of their isolation or distance from neighboring and infected populations (McCallum et al., 2001). As a consequence, prevalence of virus antibody and the prevalence of parasites, will reflect those pathogens that persist at low host population levels (Shellam, 1994).

A serosurvey of island house mice by Moro et al. (1999) on arid Thevenard Island in Western Australia reported antibodies to only one of 14 murine viruses tested. This is in contrast to serosurveys of free-ranging house mice in southeastern Australia that detected antibodies to up to eight of 14 common murine viruses, as well as the bacterium *Mycoplasma pulmonis* (Singleton et al., 1993; Smith et al., 1993).

This study was motivated by an interest in house mice as an invasive species on islands. We aimed to document parasites and antiviral antibodies of house mice inhabiting two islands in an effort to identify the current diversity of pathogens present in populations of house mice that have been geographically isolated for a long period of time.

MATERIALS AND METHODS

Study sites

Two islands were selected where house mice were introduced inadvertently by humans, established populations, and represent geographic and climatic extremes: Macquarie Island in the subantarctic and Boullanger Island off the arid Western Australian coastline.

Macquarie Island (54°30′S, 158°57′E) lies 1,100 km southwest of New Zealand and 1,700 km north of the Antarctic continent (Fig. 1a), and is 12,800 ha. The climate is cold and wet, with summer and winter mean daily maximum

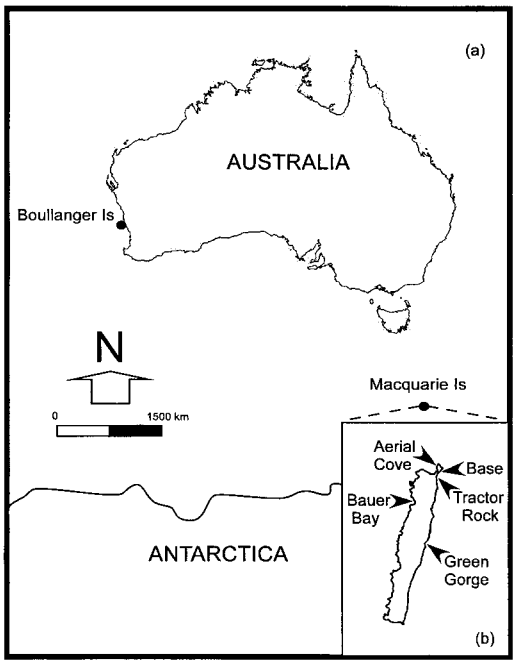

FIGURE 1. Sampling of house mice occurred at two islands around Australia: semi-arid Boullanger Island (May 1998, 2001) and at five locations across subantarctic Macquarie Island (November and December 2000).

temperatures of 7.8–8.6 C, and 4.8–5.0 C, respectively. Precipitation is high at 903.5 mm per year. House mice were first reported on Macquarie Island in 1890 (Cumpston, 1968), although their introduction to the island may have been as early as 1812 from shipwrecks, or they may have been inadvertently introduced with cargo and provisions by sealers using the island as a base for their activities (Cumpston, 1968). House mice are currently widespread across the island, occupying all habitats, but remaining predominant around the periphery of the island where vegetation is thick (Pye, 1984). The mice often invade field huts and food stores of people working on Macquarie Island.

Boullanger Island (30°18′S, 115°02′E) lies approximately 500 m offshore from the Australian mainland (Fig. 1a). The island is small in size (25 ha), and the vegetation is arid. The region has a Mediterranean climate with mean maximum temperature of 26 C in January and February and mean minimum temperature of 12 C in July. Average annual rainfall is approximately 750 mm. A seasonal drought occurs during the summer months from November to March. There are no official records reporting the presence of house mice on Boullanger Island, but they are believed to have arrived as recently as 1985 (Fuller and Burbidge, 1987). On Boullanger Island, house mice occur in very high densities across all habitats (40–700/ha, Dickman, 1992).

Study species

Previous isozyme surveys of house mice collected by Berry and Peters (1975) suggest that house mice on Macquarie Island show affinities with *M. domesticus* based upon similarities of alleles from the Hbb and Es-2 loci (Berry and Peters, 1975). Although no isozyme surveys of house mice have been conducted on individuals from Boullanger Island, it is likely they are also *M. domesticus* (see Singleton and Redhead, 1990).

Field collections

At each site, Elliott aluminium folding traps (Elliott Scientific, Upwey, Victoria, Australia) baited with peanut butter and oats, were used to capture mice. Up to 100 traps were set in lines spaced at 10 m each afternoon and checked for mice in the morning and late afternoon of subsequent days. Power analysis estimated that a minimum sample size of 20 house mice would provide a 95% probability of detecting at least one seropositive mouse in a population with an expected prevalence of 10% (Canon and Roe, 1982). Trapping at each site was continued until the minimum sample size was attained or until time did not permit further trapping when captures were low.

On Macquarie Island, collections of house mice were made during the subantarctic summer of November–December 2000. Five sites were sampled, ranging from areas close to regular human activity, to those further afield (Fig. 1b). Traps were placed among the tussock grasses (*Poa foliosa*) or Macquarie Island cabbage plants (*Stilbocarpa polaris*) where mice are known to occur (Pye, 1984). At those field sites that were located away from the base laboratory of the Australian Antarctic Division (AAD), house mice were individually kept alive in each trap during the trapping period, and transferred into separate cotton bags prior to being transported back to the AAD base laboratory.

Collections of house mice on Boullanger Island followed the same protocol as those on Macquarie Island, except that the smaller size of this island allowed traps to be set across the breadth of the island. Each house mouse captured was kept alive in a cotton bag and transported to the nearby town of Jurien each day for processing. Trapping and sampling was conducted twice, once in May 1998 and once in May 2001.

Serology

Approximately 240 μl of blood was drawn into heparinized microhematocrit tubes (Fortuna, Bildacker, Germany) from the infraorbital blood sinus. Only adult mice (>10 g female, >11 g male; Pye, 1993) were bled because of the volume of blood required for later plasma assays for viral antibodies. Blood samples were immediately centrifuged at 15,000 × G for 5 min. Hematocrit was measured for each individual sample and the plasma was separated into autoclaved Eppendorf tubes that were sealed and frozen at −80 C. Salivary glands were also collected and stored at −80 C for later assay. Tubes were transported in liquid nitrogen to the laboratories in Western Australia for later analysis of viral antibodies.

Sera were primarily tested by enzyme-linked immunosorbent assay (ELISA) for antibody directed against the following 11 viruses and two bacteria: murine cytomegalovirus (MCMV), ectromelia virus (ECT), lymphocytic choriomeningitis virus (LCMV), mouse hepatitis virus (MHV), minute virus of mice and mouse parvovirus (combined test using recombinant antigen; PARV), pneumonia virus of mice (PVM), reovirus type 3 (REO), epizootic diarrhea of infant mice (ROTA), Sendai virus (SEND), Theiler's murine encephalomyelitis virus (TMEV), *Mycoplasma pulmonis* (PULM), and *Clostridium piliformis* (TYZ). Immunofluorescence assays and ELISAs were performed to detect all antibodies except for MCMV, which was conducted at the Murine Virus Monitoring service laboratories (Adelaide, South Australia). Enzyme-linked immunosorbent assay for MCMV antibodies was performed as described by Lawson et al. (1988) with modifications as described by Moro et al. (1999). Equivocal samples were re-tested by immunofluorescence assay as described in Moro et al. (1999). Positive titers were defined as those >1:10 for all assays.

Viral detection

For detection of viral DNA in salivary glands, 100 μl of salivary gland homogenate was treated at 37 C overnight with proteinase K (10 mg/ml) and sarkosyl (10%) followed by two phenol:chloroform and one chloroform: isoamyl alcohol (24:1) extractions. DNA was precipitated by addition of an equal volume of isopropanol and the samples incubated at 80 C for 30 min. Tubes were centrifuged to pellet precipitated DNA and the pellet resuspended in 100 μl nuclease free water. A 2.5 μl aliquot was used in a 25 μl PCR reaction mix (Applied Biosystems PCR and reagent instructions). Primers used were: *ie1* (Vie2R) 5′-ACACACATCTCTGACTTAAAC-3′ and *ie1* (Vie3F) 5′-CGTCCGCTGTGACCTGACTCT-3′ and are specific for the immediate early 1 region of the viral genome and contained within the HindIII L fragment of the MCMV K181 genome (van Dommelen, 2000).

Polymerase chain reaction (PCR) was conducted in an automated thermocycler (GeneAmp PCR System 2400, PerkinElmer, Boston, Massachusetts, USA) by denaturing 1 min at 94 C, annealing at 50 C 1 min, and extension for 2 min at 60 C for 25 cycles. Polymerase chain reaction products (640 base pairs) were resolved and visualized by ethidium bromide stained agarose gel electrophoresis (Sambrook et al., 1989).

Individual parameters

Body measures (head-vent, tail-vent), sex, body mass, and breeding condition (reproductive, non-reproductive) were recorded for each individual following searches for ectoparasites (below). Males with scrotal testes, and females either pregnant or lactating, were classified as reproductive.

Parasitology

A thin film of whole heparinized blood from each individual was smeared on a slide cleaned with absolute ethanol, air-dried, stained in Giemsa, and examined at 1,000 × under oil immersion for blood protozoa and microfilariae.

House mice were euthanized by cervical dislocation. Each mouse was placed on a large white card and immediately searched for ectoparasites with probes of the entire fur. Particular attention was paid to the head (lips, ears, nasal passages) and genitalia. Ectoparasites were fixed in 70% alcohol with 5% glycerol and later identified using keys from Dunnet and Mardon (1974).

Mice were screened for endoparasites by macroscopic examination of the heart, liver, pancreas, kidney, lung, and the inner surface of the skin and by microscopic examination of alcohol-fixed gastrointestinal tract and fresh fecal pellets. Endoparasites were fixed in 70% ethanol and identified to species where possible. Fecal pellets were stored frozen and later smeared and stained with a 5% aqueous malachite green (2–5 μl) solution and scanned under 100–1,000 × binocular compound microscope. Identification for *Syphacea obvelata* was on the basis of egg size (for gravid females) and spicule size for males Levine (1980). Identification for *Rodentolepis fraterna* was based on the shape and size of scolex hooks and the size of the eggs (Baer and Tenora 1970, but following taxonomic revision from Czaplinski and Vaucher, 1994).

Fecal samples positive for *Giardia* and *Cryptosporidium* were further screened using the

TABLE 1. Trap data, population demographics, and blood hematocrit values for house mice collected from Macquarie Island (2000) and Boullanger Island (2001). Values for body measures, body mass, and hematocrit represent mean (standard deviation).

		Macquarie Island						
		Aerial Cove	Base	Tractor Rock	Bauer Bay	Green Gorge	Total	Boullanger Island
Number		28	36	27	32	33	156	54
Trap success (%)		8	15.4	13.1	12.6	7.1	11.2	43.6
Sexes	M	13	25	12	18	18	86	24
	F	15	11	15	14	15	70	30
	M:F	0.8	2.3	0.8	1.3	1.2	1.2	0.8
Body measures (mm)	HV[a]	80.9	89.4	86.1	84.7	80.7	85.0	75.9
		(11.1)	(5.6)	(5.1)	(5.8)	(7.4)	(7.2)	(5.6)
	TV[b]	74.1	78.3	76.7	74.3	71.8	75.3	77.1
		(9.2)	(5.4)	(4.5)	(5.1)	(7.8)	(6.5)	(4.4)
	HV:TV	1.0	1.1	1.1	1.1	1.1	1.1	0.9
Body mass (g)		16.7	17.8	16.6	15.7	14.9	16.3	14.4
		(5.7)	(2.9)	(2.7)	(3.1)	(3.3)	(3.4)	(2.0)
Hematocrit (%)		64	63	58	63	55	61	53
		(3.8)	(3.9)	(4.9)	(2.5)	(17.3)	(3.2)	(4.2)
Range		60–70	55–70	50–65	60–65	15–70	15–70	40–62

[a] Head-vent.
[b] Tail-vent.

procedures of Hopkins et al. (1997), Morgan et al. (1997, 2001), and Read et al. (2001) in order to genotype each parasite isolate. Molecular characterization was carried out using PCR amplification and sequencing of the small subunit-rDNA gene (SSU-rDNA) of a 130 bp region for *Giardia* and an ~830 bp region for *Cryptosporidium*.

Data analysis

Trap success (number of mice captured divided by the product of the total number of traps used and the total number of trapping nights) was used as an index of abundance. Comparisons of body size and mass between sites on Macquarie Island and between islands, were performed with normalized data using *t*-tests or one-way analysis of variance.

Parasite population parameters are reported according to Bush et al. (1997). Chi-square analysis was used to compare significant ($P<0.05$) differences between group prevalences. The chi-square correction for continuity was used where appropriate degrees of freedom require it (Parker, 1983). All calculations were conducted using SPSS version 11 (SPSS Inc., 2002).

RESULTS

Population parameters

A total of 156 house mice were trapped on Macquarie Island and 54 on Boullanger Island. Trap success was low on Macquarie Island and averaged 11.2% compared to 43.6% on Boullanger Island (Table 1). Highest captures on Macquarie Island occurred around the AAD base station. Trap success was lowest at Green Gorge which represented the furthest site from human activity. There were few individuals with morphologic evidence of reproduction on Macquarie Island, representing two (1.2%) males and eight (5.0%) females. On Boullanger Island, reproductive individuals represented eight (14.8%) males and nine (16.7%) females. Sex ratios for all sites combined on Macquarie Island and on Boullanger Island were close to parity. There was a bias towards males at the AAD base station (Chi-square=1.64, d.f.=1, $P=0.02$).

House mice on Macquarie Island were on average longer in body size ($t_{123}=6.04$, $P<0.001$) and heavier ($t_{123}=2.84$, $P=0.005$) than those from Boullanger Island (Table 1). However, tail length did not significantly differ between islands, emphasizing that the larger size of the Macquarie Island house mice was indeed related to

TABLE 2. Prevalence (%) of murine ectoparasites and endoparasites from Macquarie Island (2000) and Boullanger Island (2001).

Parasite	Macquarie Island						Boullanger Island
	Aerial Cove	Base	Tractor Rock	Bauer Bay	Green Gorge	Total	
Ectoparasites							
Nosopsyllus fasciatus	0	0	7	9	0	4	0
Xenopsylla australiaca	0	0	0	0	0	0	13
Number tested	28	36	27	32	33	156	54
Endoparasites							
Cestoda							
Rodentolepis fraterna	9	39	8	17	10	18	30
Nematoda							
Syphacea obvelata	9	4	8	52	15	19	0
Protozoa							
Coccidian oocysts	0	17	20	13	10	14	0
Cryptosporidium andersoni	9	0	0	0	5	2	0
Giardia sp.	9	13	8	22	30	17	71
Number tested	11	23	25	23	20	102	27
Blood parasites	0	0	0	0	0	0	0
Number tested	11	23	25	23	20	102	27

their body size and not tail length. Furthermore, body size varied significantly across sites on Macquarie Island ($F_{4,93}=5.76$, $P<0.001$); mice from Base were larger (Tukey HSD $P<0.05$) in body size to those captured from either Aerial Cove or Green Gorge.

Hematocrit was significantly higher in house mice from Macquarie Island (61±3.2%) compared to those on Boullanger Island (53±4.2%, $t_{208}=5.65$, $P<0.001$, Table 1). Hematocrit also varied significantly between sites on Macquarie Island ($F_{4,152}=2.63$, $P=0.04$), and was a low 15% in one individual from Green Gorge.

Parasitology

A total of 156 house mice from Macquarie Island and 54 house mice from Boullanger Island were examined for ectoparasites. Prevalence of ectoparasites was low for house mice on both islands (Table 2). Only one species of flea was found from house mice on each island: *Nosopsyllus fasciatus* on Macquarie Island and *Xenopsylla australiaca* on Boullanger Island. The intensity of fleas was low, averaging 2.3±1.0 and 4.2±1.2 for house mice on Macquarie Island and Boullanger Island, respectively. On Macquarie Island, fleas were only detected on house mice from Tractor Rock and Bauer Bay. Ectoparasites have been deposited with the Western Australian Museum (Perth, Western Australia; Accession numbers WAM 34000–34001).

A total of 102 house mice from Macquarie Island and 27 house mice from Boullanger Island were examined for endoparasites and blood parasites using microscopy. Of these, 73 (72%) and 10 (37%) yielded at least one type of endoparasite respectively. No blood parasites were found in house mice from either island. Microscopic searches of the gut and faeces for parasites revealed five taxa (Table 2). Endoparasites have been deposited with the Western Australian Museum (Accession numbers WAM V 4379–4381).

Five *Giardia* 'genotypic' assemblages (A, C, D, plus two novel genotypes) were found among 78% ($n=37$) of house mice on Macquarie Island and 71% (genotype A, $n=7$) on Boullanger Island using molecular techniques. *Cryptosporidium andersoni* occurred in 32% ($n=19$) of house

TABLE 3. Prevalence (%) of murine antiviral antibodies in house mice collected on Macquarie Island (2000) and Boullanger Island.

	Macquarie Island						Boullanger Island	
Virus[a]	Aerial Cove	Base	Tractor Rock	Bauer Bay	Green Gorge	Total	1998	2001
Number tested	16	23	23	13	17	92	34	27
MCMV[b]	81	83	96	92	42	85	77	0[b]
PARV	69	13	22	8	0	17	—	0
ROTA	63	4	9	0	41	13	—	4
TMEV	69	39	39	77	53	50	—	0
Number tested	16	11	11	8	17	63	—	14
TYZ	0	9	0	0	0	2	—	0
LCMV	0	0	0	0	12	2	—	0

[a] MCMV = murine cytomegalovirus; PARV = minute virus of mice and mouse parvovirus; ROTA = epizootic diarrhea of infant mice; TMEV = Theiler's murine encephalomyelitis virus; TYZ = *Clostridium piliformis*; LCMV = lymphocytic choriomeningitis virus.

[b] Polymerase chain reaction revealed 85% of mice positive for MCMV.

mice sampled from Macquarie Island but was not detected from Boullanger Island.

The prevalence of cestodes in house mice trapped from the AAD base site was highest compared with other sites on Macquarie Island. Of interest was one house mouse from AAD base which yielded 72 *Rodentolepis fraterna* scolesces collected from its small intestine. Nematodes were not equally represented in house mice across sites on Macquarie Island; their highest prevalence was found in house mice from Bauer Bay (Chi-square=21.5, d.f.=4, $P<0.001$). The prevalence of gut parasites in house mice on Boullanger Island was lower than on Macquarie Island, with cestodes represented in almost 30% of house mice on Boullanger Island.

No significant difference was found between two age groups, based on body mass (individuals up to 15 g, individuals above 15 g) for any parasite taxon. Similarly, there was no significant relationship between sex and infection on either Macquarie Island or Boullanger Island.

Serology

Of 92 house mice from Macquarie Island screened for virus antibody, 63 were subjected to more extensive screening that included antibodies to the viruses SEND, LCMV, ECT, REO, and the bacteria PULM and TYZ. Antibodies were detected to six pathogens: MCMV, PARV, ROTA, TMEV, LCMV, and TYZ (Table 3). Seroprevalence was highest for MCMV, occurring in 85% of house mice sampled. Seroprevalence to MCMV varied significantly between sites (Chi-square=42.3, d.f.=4, $P=0.041$) and ranged from a minimum of 43% at Green Gorge to a maximum of 96% at Tractor Rock (Table 3). Average antibody titer to MCMV was highest at Aerial Cove (dilution 1:177±5.3) and lowest at AAD base (dilution 1:41±8.3). Confirmation of MCMV within salivary glands was recorded for 100% of house mice on Macquarie Island using PCR. Antibody to TMEV was present in half of the house mice screened. In contrast to MCMV, seroprevalence to TMEV did not significantly differ between sites. Seroprevalence to LCMV and TYZ was only reported from the Base and Green Gorge sites, respectively.

On Macquarie Island, seroprevalence to MCMV or TMEV between sexes did not differ. However, heavier mice were more likely to be seropositive to MCMV (17.1±2.9 g, $t_{98}=3.30$, $P<0.001$) than mice where antibody to this virus was not detected (14.8±2.4 g). There was no significant difference in the body mass of house mice with or without antibodies to TMEV.

Multiple infection was common among individual mice. Three house mice had evidence of infection with four viruses (MCMV, PARV, ROTA, TMEV or MCMV, ROTA, TMEV, LCMV), 12 with three viruses (of which 58% comprised infection with MCMV, PARV, TMEV), 26 with two viruses (75% with MCMV and TMEV), and 60 house mice were seropositive to only one virus.

Antibodies to two viruses, MCMV and ROTA were detected on Boullanger Island (Table 3). In 1998, seroprevalence to MCMV was 77% (no tests were conducted for the other viruses at this time). In contrast, screening of additional sera in 2001 revealed that no antibodies to MCMV could be detected with ELISA. However, PCR confirmed the presence of MCMV DNA sequence in 85% of house mice. Occurrence of MCMV in house mice from Boullanger Island did not vary with sex or body mass.

DISCUSSION

The diversity of ectoparasites recorded from house mice is variable, and particularly so between island and mainland populations. Whitaker (1970) found 16 taxa of ectoparasites among house mice in Indiana (USA). In Australia, 12 species of ectoparasites have been reported from house mice (Dunnet and Mardon, 1974; Singleton, 1985). Diversity is lower among island populations: on Hawaii, five species of flea have been reported (Alicata, 1969), and in the Outer Hebrides Islands, two species (Elton, 1934). On Macquarie and Boullanger Islands, only one species of flea was recorded from house mice on each island.

Like ectoparasites, the diversity of endoparasites is low among populations of house mice inhabiting islands (Spratt, 1987; Pisanu et al., 2001). This relationship is likely to be a function of the population size of the host (Tompkins et al., 2002). On Macquarie Island, five endoparasite taxa were recorded, and on Boullanger Island, one taxon. Diversity of endoparasites reported from house mice across Australia is higher at 23 taxa (Mackerras, 1958; Singleton, 1985; Singleton and Redhead, 1990). No blood parasites were found in either island population. Except for *Hepatozoon muris* (O'Donoghue and Adland, 2000), there is no record of blood parasites in house mice in Australia.

Syphacea obvelata was found at lower prevalence in house mice from Macquarie Island (19%) than has been reported from house mice in Australia (67%; Singleton, 1985). *Syphacea obvelata* was also found in house mice sampled from several subantarctic islands of the Indian Ocean (Pisanu et al., 2001); indeed, this nematode was the only helminth recorded in house mice there. Like *S. obvelata, R. fraterna* also shows variability in occurrence; it was absent from house mice on Kerguelen Island and its adjacent archipelago (Pisanu et al., 2001), but it occurred in approximately 18% of house mice sampled from Macquarie Island and almost 30% from Boullanger Island.

Seroprevalences to murine viruses among house mice on Macquarie and Boullanger Islands were also lower to those reported from house mice inhabiting mainland sites (Moro et al., 1999). On Macquarie Island, house mice were seropositive to five viruses and *C. piliformis.* On Boullanger Island, only antibodies to ROTA were detected, however, MCMV was detected from salivary glands by PCR in 2001 even though the host population did not elicit a detectable antibody response as measured by ELISA.

Antibodies against TMEV have not been found in serosurveys of house mice across Australia (Singleton et al., 1993; Smith et al., 1993; Moro et al., 1999). Seroprevalence to TMEV on Macquarie Island was high, occurring among half the house mice sampled, and across all sites. Its presence in this isolated population may reflect a non-Australian origin of the hosts that founded this population (Cumpsten, 1968).

The relationship between viral persistence and population density has parallels

with human population studies. For example, it is known that measles virus shows dependency upon a human population that remains above a (host) threshold of approximately 500,000 people (Black, 1966). In contrast, varicella zoster virus can survive in small human populations by establishing latent infection (Black, 1966). Murine cytomegalovirus is known to remain latent in its host (Shellam, 1994). Stressors may reactivate MCMV and contribute to spread of the virus; infection and persistence of MCMV in the population can thus be maintained. Consequently, viral persistence in areas experiencing large changes in host density should be influenced and restricted to those viruses that persist at low host densities (but see McCallum et al., 2001).

Relatively low levels of exposure to murine viruses among populations of house mice on Boullanger Island, Macquarie Island, and Thevenard Island (Moro et al., 1999) raises questions about persistence of virus in remote locations. There are two hypotheses for the observed paucity of murine viruses (and possibly parasites) observed on these islands that are inherently linked to the recruitment and population dynamics of the host species on each island (McCallum et al., 2001).

The first hypothesis is that viral diversity reflects what founder house mice transferred to the island. This may explain a paucity of helminth parasites among introduced small mammals on several French subantarctic islands (Pisanu et al., 2001). Evidence of TMEV among Macquarie Island house mice, yet its absence from mice sampled across Australia, supports this hypothesis. A second hypothesis is that viral diversity may be dependent upon mouse population densities. For example, seroprevalence to MCMV is influenced by density of house mouse populations (Smith et al., 1993; Moro et al., 1999; Singleton et al., 2000). Small mammal populations on some arid islands undergo periods of boom and bust in response to periods of drought and rains typical of many arid zone mainland populations (Southgate and Masters, 1996; Dickman et al., 1999). Similar cycles in mouse densities occur on arid Thevenard Island off Western Australia (Moro and Morris, 2000). Densities of house mice on Boullanger Island undergo major boom and bust cycles across the year, with densities high in summer and low in winter (D. Moro, pers. obs.). This annual change in population size may have been sufficient to purge those pathogens from the host population on Boullanger Island which could not persist at low (winter) population densities. These two hypotheses are not mutually exclusive, and it is likely that both mechanisms have played a part to explain the pattern of pathogen diversity observed in island house mice.

The potential of house mice as reservoirs for transmission of pathogens, such as *Cryptosporidium* (Sinski et al., 1998), to humans and other mammals on islands, is worth recognizing. With the introduction of new (and carrier) hosts, or with an increase in the density of a host, the opportunity exists that pathogens may spread across an island. An epizootic is particularly possible if the main reservoir host for a pathogen already occurs on an island and interacts directly or indirectly with humans or local, and possibly endemic, fauna.

Occurrence of pathogens such as *Giardia, Cryptosporidium,* and LCMV in house mice raises concerns about the risks these rodents pose to humans in isolated communities. House mice might present a source of infection if their densities were high and they invaded human dwellings and food stores. *Cryptosporidium* may cause illness to humans (Goodgane et al. in Sinski et al., 1998; Gatei et al., 2002) that are essentially quarantined on Macquarie Island for up to 18 mo. The occurrence of *C. andersoni* on Macquarie Island is interesting, though it remains unclear whether house mice are an important source of transfer of this microbe to humans and other species by water-borne or food-borne routes. Likewise, the presence of LCMV is of particular concern because

it is transmissible to humans during pregnancy (Barton and Mets, 2001).

Surveys for murine viruses and parasites on islands off Australia have demonstrated fewer pathogens when compared to house mouse populations from mainland Australia. In addition, the diversity of antiviral antibodies was lower on arid islands than on one subantarctic island. Although serology is not an optimal test to screen for murine viruses, it does serve as a benchmark and provides evidence of viral activity.

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