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Technical Note

A review of necrophagous insects colonising human and animal cadavers in south-east Queensland, Australia

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ABSTRACT

A review of insects collected from decomposing human remains in south-east Queensland yielded 32 species in three orders (Diptera, Coleoptera, Hymenoptera) and 11 families (Calliphoridae, Sarcophagidae, Muscidae, Phoridae, Sepsidae, Chironomidae, Dermestidae, Cleridae, Histeridae, Staphylinidae, Encyrtidae). There were 15 cases where remains were located indoors and five cases where remains were outdoors, in both terrestrial and aquatic environments. Coleoptera were strongly associated with outdoors remains, while dipteran species composition was similar in both indoor and outdoor habitats. Some Diptera were only associated with indoors remains, while others were similarly restricted to remains recovered outdoors. Hymenopteran parasitoids were active in both habitats. Comparative collections were made from other vertebrate remains, including road-kill and farmed animals throughout south-east Queensland (Qld) and northern New South Wales (NSW) during the same period.

1. Introduction

Q4 A common legal challenge for forensic entomology relates to the scientific validity of substituting vertebrate remains for human remains in baseline studies [1]. Due to the legal and ethical issues of using human cadavers for research, forensic entomologists have used a variety of vertebrate animals (Table 1) to observe insect succession and generate the baseline data used for post mortem interval estimates in medicolegal cases. Pigs are by far the most internationally accepted human.

This study was initiated to determine the range of necrophagous insects attracted to human remains in south-east Queensland (Qld), and to compare the species observed with those that inhabit other vertebrate remains in the same region. Of the 20 cases reviewed at the Brisbane mortuary, there were 15 cases where remains were located indoors and five cases where remains were outdoors, in both terrestrial and aquatic environments. Coleoptera were strongly associated with outdoors remains, while dipteran species composition was similar in both indoor and outdoor habitats. Some Diptera were only associated with indoors remains, while others were similarly restricted to remains recovered outdoors. Hymenopteran parasitoids were active in both habitats.

2. Materials and methods

Access to decomposing human remains was obtained through the Queensland Health Forensic and Scientific Services (QHFSS) mortuary in Brisbane.

Approvals for entomological research were granted by Queensland Health, the Queensland Police Service, and The University of Queensland, with the following permits issued:

I. Queensland Health Human Research Ethics Committee approval number FSS-HEC AU/1/0FF9012.
II. Approval as a 'Genuine Researcher' under S.53(7) Queensland Coroners Act 2003.
III. The University of Queensland Medical Research Ethics Committee, project number 2011001124.

During the period December 2011–January 2014, necrophagous insects inhabiting human remains found in outdoor and indoor environments in south-east Queensland (Qld) were collected. Remains had been stored in a cool room running at 4 °C after delivery to the mortuary and prior to autopsy. The time between

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Table 1
Summary of vertebrate remains used in decomposition studies to obtain insect succession data.

Author	Location	Animal model
Payne 1965 [3]	South Carolina, USA	Pigs
Richards and Goff 1997 [4]	Hawaii, USA	Pigs
Anderson et al. 2002 [5]	Alberta, Canada	Pigs
Archer 2003 [6]	Victoria, Australia	Pigs
Matuszewski et al. 2008 [7]	Western Poland	Pigs
Sharanowski et al. 2008 [8]	Saskatoon, Canada	Pigs
Eberhardt and Elliot 2008 [9]	Auckland, New Zealand	Pigs
Voss et al. 2008 [10]	WA, Australia	Pigs
Voss et al. 2009, 2011 [11,12]	WA, Australia	Pigs
Anderson 2011 [13]	Alberta, Canada	Pigs
Fuller 1934 [14]	ACT, Australia	Rodents
Kočárek 2003 [15]	Opava, Czech Republic	Rodents
Azwandi et al. 2013 [16]	Selangor, Malaysia	Rodents
Johnson 1975 [17]	Illinois, USA	Rabbits
Tantawi et al. 1996 [18]	Alexandria, Egypt	Rabbits
Bourel et al. 1999 [19]	Ambleteuse, France	Rabbits
Bachmann and Simmons 2010 [20]	Lancashire, UK	Rabbits
Azwandi et al. 2013 [16]	Selangor, Malaysia	Rabbits
Ahmad and Ahmad 2009 [21]	Kedah, Malaysia	Monkeys
Ahmad et al. 2011 [22]	Kedah, Malaysia	Monkeys
Azwandi et al. 2013 [16]	Selangor, Malaysia	Monkeys
Braak 1986 [23]	Transvaal, South Africa	Antelope
O'Flynn and Moorhouse 1979 [24]	Queensland, Australia	Macropods
Reed 1958 [25]	Tennessee, USA	Dogs
Jiron and Cartin 1981 [26]	Costa Rica	Dogs
O'Flynn 1983 [27]	Queensland, Australia	Dogs
O'Flynn and Moorhouse 1979 [24]	Queensland, Australia	Cats
O'Flynn 1983 [27]	Queensland, Australia	Cats
O'Flynn 1983 [27]	Queensland, Australia	Sheep
Johnson 1975 [17]	Illinois, USA	Squirrels
Lang et al. 2006 [28]	Tasmania, Australia	Possums
Bornemissza 1957 [29]	Perth, Australia	Guinea pigs
Cornaby 1974 [30]	Costa Rica	Reptiles
Nelder et al. 2009 [31]	Alabama, USA	Reptiles
Rodriguez and Bass 1983 [32]	Tennessee, USA	Humans
Rodriguez and Bass 1985 [33]	Tennessee, USA	Humans
Schoenly et al. 2002, 2007 [2,34]	Tennessee, USA	Humans

delivery of the remains to the mortuary and insect collection was usually 2–3 days.

Dipteran adults, pupae, larvae and eggs, and adult Coleoptera were collected from the cadavers, their clothing and inside body bags. Collections were made immediately prior to, and during autopsy. Most of the eggs and larvae found were placed onto fresh kangaroo mince for rearing, while some were killed in hot water and preserved in 70% alcohol. Pupae were rinsed in water, dried and placed into 40 ml disposable plastic containers with perforated lids to continue development. Adults were collected and killed by freezing if not already dead in the clothing and body bag.

Eggs, larvae and pupae were reared under ambient conditions in Toowoomba, Qld then identified as adults using published taxonomic keys.

Specimens were collected in the presence of mortuary staff, and sometimes investigating police. Decedent information recorded included stage of decomposition, age, gender, date last known to be alive, date delivered to the mortuary, date of insect collection, location and type of death scene, and manner of death.

Collected insects were identified to species wherever possible using the taxonomic keys referenced above, reference to collections held by The Queensland Museum (QM) and the Australian National Insect Collection (ANIC), or with assistance from entomologists (Bryan Cantrell, Sasha Voss, Jocelyn King).

Based on an insect succession study conducted over two years using pigs, a list of forensically important Diptera for south-east Qld was created [35]. Comparative collections were conducted on an opportunistic basis on more than 80 road-kills and other dead vertebrate remains from central Qld through to central NSW during the same period as the mortuary study. Vertebrate remains examined included kangaroos and wallabies (*Macropus* spp. $n \geq 40$), feral pigs (*Sus scrofa* $n \geq 20$), sheep (*Ovis* sp. $n = 5$), cattle (*Bos taurus* $n = 2$), red foxes (*Vulpes vulpes* $n = 3$), rats (*Rattus norvegicus* $n = 2$) and rabbits (*Oryctolagus cuniculus* $n = 5$). Decomposition stages ranged from fresh to skeletonised.

The same collection, rearing and identification procedures were followed. These data were compared with insect taxa collected from 20 human remains at the Queensland Health Forensic and Scientific Services mortuary in Brisbane.

3. Results

From a total of 20 cases, there were four females and sixteen males with an age range of 29 to over 70 years. Manner of death included six non-suspicious/natural causes, seven suicides, one accidental poisoning, one probable homicide and five undetermined. The periods between the discovery of the cadaver and time when last known to be alive ranged between 2 days and 6 weeks. The majority of cases originated from urban areas in the Brisbane and Gold Coast regions (Table 2).

In total, 32 insect species representing 3 orders (Diptera, Coleoptera, Hymenoptera) and 11 families (Calliphoridae, Sarcophagidae, Muscidae, Phoridae, Sepsidae, Chironomidae, Dermestidae, Cleridae, Histeridae, Staphylinidae, Encyrtidae) were collected and identified. Within the 20 cases, 15 remains were indoors, and five were outdoors (Table 3), including one suicide in a car with open windows in bushland, and one homicide dumped in a river. In all cases, marbling and skin slippage were observed on the remains, regardless of the stage of decomposition.

A total of 20 species were collected from the 15 indoors cases, while 24 species were collected from the five outdoors cases. There was greater diversity seen in the outdoors cases, with 11 families represented, compared with six families from the indoors cases (Table 3). Insects listed as unidentified were usually too damaged by body fluids, clothing or body bags for reliable identification beyond family level. *Ch. rufifacies*, *S. crassipalpis*, *L. cuprina* and *Ch. megacephala* were the most frequently collected species from indoors cases, while *Ch. saffranea*, *Ch. rufifacies*, *Ch. nigripes* and *Ch. megacephala* were most frequently encountered on cases originating outdoors. The Sarcophagids were most prevalent in cases originating indoors. In very few of the indoors cases covered in this study were the dwellings closed or sufficiently well screened to impede insect access.

Calliphorids were present in 15 of the 20 cases (75%), with the next most frequently encountered family being the Sarcophagids, present in 9 of the 20 cases (45%). Overall, *Ch. rufifacies* occurred most frequently, being found in 55% of the cases, followed by *Ch. saffranea* (present at 40% of cases), *Ch. megacephala* (present at 35% of cases) and *S. crassipalpis* (present at 35% of cases).

Hymenopteran parasitic wasps were collected after emergence from dipteran pupae in two mortuary cases.

The inspections conducted on road-kill and farmed livestock resulted in the observation or collection of at least 42 species from four orders and 16 families. It is possible that some less common or cryptic species were missed, as searches were often not as exhaustive as those done on human remains due to time or safety constraints. Some carcasses (sheep, cattle) were visited more than once.

The most common dipteran species collected or observed from over 80 road-kill or other dead animal remains were *Ch. rufifacies*,

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Table 2
Summary of decedent's personal details from the Brisbane mortuary cases.

Case No	Gender	Age (years)	Weight (kg)	Manner of death	Clothes	Decomp	Habitat
2011-01	♀	>70	Unknown	Non-suspicious	Partial	Early	Indoors
2011-02	♀	60–70	>75	Non-suspicious	Naked	Early	Indoors
2011-03	♂	>70	∼60	Non-suspicious	Partial	Early	Indoors
2011-04	♂	64	>100	Non-suspicious	Partial	Advanced	Indoors
2011-05	♂	46	∼70	Suicide – CO poisoning	Entirely	Advanced	Outdoors
2012-01	♂	29	50	Suicide-hanging	Entirely	Advanced	Outdoors
2012-02	♀	50	75	Suicide – drug overdose	Partial	Early	Indoors
2012-03	♂	35	43	Non-suspicious	Entirely	Early	Indoors
2014-04	♂	49	78	Drug overdose	Partial	Advanced	Indoors
2012-05	♂	>60	Unknown	Alcoholism	Entirely	Advanced	Indoors
2012-06	♂	69	63	Non-suspicious	Partial	Early	Indoors
2012-07	♂	46	86	Suicide	Entirely	Early	Indoors
2012-08	♀	38	49	Unknown	Entirely	Moderate	Indoors
2012-09	♂	60	59	Suicide	Entirely	Advanced	Indoors
2012-10	♂	68	81	Non-suspicious	Naked	Moderate	Indoors
2012-11	♂	35	Unknown	Suicide – gas	Partial	Advanced	Indoors
2013-01	♂	40	78	Alcoholism	Entirely	Early	Outdoors
2013-QPS	♂	31	∼75	Homicide	Partial	Early	Aquatic
2014-01	♂	54	∼65	Undetermined	Partial	Advanced	Outdoors
2014-02	♂	59	Unknown	Non-suspicious	Partial	Advanced	Indoors

C. augur, *Ch. saffranea*, and *Ch. varipes* with *Ch. rufifacies* by far outnumbering all other species. *Saprinus cyaneus*, *Necrobia rufipes*, *Creophilus erythrocephalus* and *Dermestes maculatus* were the most commonly encountered Coleopterans, with the first three species listed being maggot predators.

The list of species from non-human vertebrates is comparable with the most frequently collected species from human remains within the same broad geographical region of south-east Qld (Table 3). Habitat descriptions have been simplified into four categories – grazing describes agricultural land containing grass, shrub and tree vegetation; cropping describes agricultural land largely composed of monoculture crop or fallow paddocks with few shrubs or trees; forest describes national parks or managed plantations composed mainly of shrubs and/or trees; and urban describes domestic and commercial buildings, and their surroundings.

In Table 4, the monthly/seasonal presence of necrophagous Diptera are shown. The collections, from both human and non-human remains were largely opportunistic, so do not necessarily indicate all the months that a particular species is likely to be present in the region.

4. Discussion

In the first trials to test the widely-held assumption that pig remains are reliable analogues for human remains, insect taxa attracted to both porcine and human remains were compared at the University of Tennessee [2,34]. Over 99% of the total taxa caught by sweep nets and pitfall traps were common to both pigs and humans [34]. Between-subject comparisons revealed negligible preferences by forensically important insects for human over porcine remains [2].

While our preliminary study covered a limited time period and included a limited number of cases of decomposing human remains in the Brisbane mortuary, there is strong similarity of arthropod species attracted to both human and other vertebrate remains in the same geographical region.

A review of those insects collected yielded 32 species in 3 orders and 11 families. They were composed of 12 species (37.5%) common to both indoors and outdoors, 8 species (25%) restricted to indoors and 12 species (37.5%) collected only from outdoors cases.

In comparison, Goff [36] examined 35 cadavers in Hawaii and collected 22 species, comprising 5 species (23%) from both habitats, 14 species (64%) from indoors, and 21 species (95%) from outdoors. Possible explanations for the differences in the percentage presence observed include individual habitat preferences of species specific to Hawaii or Qld, microhabitat around the buildings or outdoor death scenes, or the difference in post mortem intervals recorded in both surveys. Recorded PMI's in Hawaii varied between 2 and 21 days [36], while the cases from the Brisbane mortuary were generally recorded from the date last known to be alive, and ranged between 2 days and over 6 weeks.

The most frequently collected species from both human and other vertebrate remains in south east Qld were *Ch. rufifacies*, *Ch. megacephala*, and the closely related *Ch. saffranea*, *C. augur*, and *Ch. varipes* (Diptera); and *N. rufipes* and *S. cyaneus* (Coleoptera). These should be considered forensically important species in the subtropical areas of Qld and northern NSW. Although *Ch. rufifacies* has been extensively studied [27,37,38], for the other species listed, published development data is sparse or non-existent, and should be the subject of further work to enable their use in PMI estimates. The early arrivals of *Chrysomya* spp. confirm observations made by others that they behave as primary blowflies in summer in Qld [24]. When comparing species collected from human and non-human remains, the grazing areas attracted a greater diversity of Diptera species to road-kill or other vertebrate remains than did urban, cropped or forested sites (Table 3). This may be a result of the more frequent occurrence of road-kill (mostly macropods) in grazed and forested areas, where timber provides cover and daytime shade for the macropods. With little shelter available, road-kill is less frequently encountered in cropped areas. In contrast, human remains found indoors attracted a greater diversity of species (Table 3).

Sukontason et al. [39] investigated the insect inhabitants of 30 human cadavers and found *Ch. megacephala* and *Ch. rufifacies* to be the most common species in indoor, outdoor, and forested areas in northern Thailand and are regarded as forensically important. Similarly, in Malaysia, Kumara et al. [40] investigated 50 cases, while Kavitha et al. [41] examined 80 cases of human remains. Both found *Ch. megacephala* and *Ch. rufifacies* to be the most frequently collected species. Based on these reports, it would be reasonably safe to suggest that *Ch. megacephala* and *Ch. rufifacies* would dominate carrion and be forensically important species in central and northern Queensland as well as in southern Qld. There are no published works on carrion-associated arthropods in central and northern Qld, however, *Ch. rufifacies*, *Ch. megacephala*, *Ch.*

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Table 3
Frequency of insects collected from 20 cases of decomposing human remains and 82 non-human vertebrate remains in various habitats.

Family	Genus/species[a]		Mortuary cases ($n=20$)		Other vertebrate remains ($n=82$) Habitat			
			Indoor	Outdoor	Grazing	Cropping	Forest	Urban
Calliphoridae	*Chrysomya rufifacies* (Macquart, 1842)	*a*	8	3	12	11	1	1
	Chrysomya rufifacies	*I*						
	Chrysomya saffranea (Bigot, 1877)	*a*	4	4	4		3	
	Chrysomya saffranea	*I*						
	Chrysomya megacephala (Fabricius, 1794)	*a*	5	2	2	2		
	Chrysomya megacephala	*I*						
	Lucilia cuprina (Wiedemann, 1830)	*a*	6	1	1			
	Lucilia cuprina	*I*						
	Chrysomya nigripes Aubertin, 1932	*a*	2	3			1	
	Chrysomya nigripes	*I*						
	Chrysomya varipes (Macquart, 1851)	*a*	3	1	5	5		
	Chrysomya varipes	*I*						
	Calliphora augur (Fabricius, 1775)	*a*	2		5	1		
	Calliphora augur I	*I*						
	Chrysomya incisuralis (Macquart, 1851)	*a*	1					
	Chrysomya semimetallica (Malloch, 1927)	*I*	1					
	Chrysomya flavifrons (Aldrich, 1925)	*a*		1	3	1		
	Calliphora stygia (Fabricius, 1782)	*a*				1		1
	Calliphora stygia	*I*					1	
	Calliphora fulvicoxa Hardy, 1930	*a*			2			
	Calliphora centralis Malloch, 1927	*a*			1			
	Calliphora hilli Patton, 1925	*a*			1			1
	Calliphora fuscofemorata Malloch, 1927	*a*	1		1			
	Calliphora ochracea Schiner, 1868	*a*		1				
	Calliphora ochracea	*I*						1
	Hemipyrellia ligurriens (Wiedemann, 1830)	*a*		2				
	Hemipyrellia ligurriens	*I*						
	Lucilia papuensis Macquart, 1843	*a*	1					
Sarcophagidae	*Sarcophaga crassipalpis* Macquart, 1839	*a*	7					
	Sarcophaga crassipalpis	*I*						1
	Sarcophaga impatiens Walker, 1849	*a*	3	1		1		5
	Sarcophaga impatiens	*I*						
	Sarcophaga aurifrons Macquart, 1846	*I*	1			2		
	Sarcophaga praedatrix Walker, 1849	*I*		1				2
	Unidentified sp.	*I*	1	1				
Muscidae	*Hydrotaea chalcogaster* (Wiedemann, 1824)	*a*	1	1	6	2		
	Hydrotaea chalcogaster	*I*						
	Synthesiomyia nudiseta (Wulp, 1883)	*I*	1					
	Musca vetustissima Walker, 1849			1				
	Musca domestica Linnaeus, 1758				1	1		
	Unidentified sp.			1				
Phoridae	*Megaselia* sp. Rondani, 1856	*a*	4	1				
	Megaselia sp.	*I*						
Sepsidae	Unidentified sp.	*a*		1				
Chironomidae	Unidentified sp.	*I*		1				
Dermestidae	*Dermestes maculatus* DeGreer, 1774		1	2	6	12	1	
	Dermestes frischii Kugelann, 1792				3			
	Dermestes ater DeGreer, 1774				2			
Cleridae	*Necrobia ruficollis* (Fabricius, 1775)			1				
	Necrobia rufipes (DeGreer, 1775)			1	5	11		
Histeridae	*Saprinus cyaneus* (Fabricius, 1775)			2	7	10	1	3
	Saprinus pseudocyaneus White, 1846				5	3	1	1
	Saprinus cupreus Erichson, 1834				1			
Staphylinidae	*Aleochara* sp. Gravenhorst, 1802			1				1
	Creophilus erythrocephalus (Fabricius, 1775)				5	10		
Silphidae	*Diamesus osculans* (Vigors, 1825)					1		
Scarabaeidae	*Aphodius* sp. Illiger, 1798				2	1		
	Onthophagus sp. Latreille, 1802					2		
Trogidae	*Omorgus* sp. Erichson, 1847					2		
Encyrtidae	*Tachinaephagus zealandicus* Ashmead, 1904		1	1				
Acaridae	*Caloglyphus berlesei* Michael, 1903				1			
Parasitidae	Unidentified sp.				1			
Laelapidae	Unidentified sp.				1			

[a] *a* = adult, *I* = immatures.

saffranea, *S. cyaneus*, and *N. rufipes* have been regularly collected or observed from macropod and feral pig road-kill in central Qld (XXX, unpublished).

The two species collected from human remains and not collected from road-kill, farmed livestock or domestic pigs used in a concurrent insect succession study were *Synthesiomyia nudiseta* (Muscidae) and *Sarcophaga crassipalpis* (Sarcophagidae). Both species are known to colonise a variety of vertebrate remains in the region (B. Cantrell, pers comm) and any individuals present were most likely missed during the carcase search.

As has been reported by Kumara et al. [40] in Malaysia, the Sarcophagids in Qld were more frequently encountered in indoor

Table 4
The immature (imm.) and adult development stages of Diptera collected from human and non-human vertebrate remains on a monthly and seasonal basis. [grey] denotes human remains. [blue] denotes non-human vertebrate remains.

		SUMMER			AUTUMN			WINTER			SPRING		
		Dec	Jan	Feb	Mar	Apr	May	Jun	Jul	Aug	Sep	Oct	Nov
Ch. rufifacies	imm.	grey/blue	grey	grey			grey/blue	blue		grey/blue	blue	blue	grey
	adult	grey/blue	grey	grey	blue								grey
Ch. saffranea	imm.	grey/blue		grey	blue			grey		grey/blue			
	adult			grey	blue								grey
Ch. megacephala	imm.						grey/blue	grey		grey			grey
	adult			grey									
Ch. nigripes	imm.			grey									grey
	adult	grey			blue								
Ch. varipes	imm.	blue								blue			grey
	adult		grey	grey	blue						blue		grey
Ch. incisuralis	adult			grey									
Ch. semimetallica	imm.									grey			
Ch. flavifrons	imm.						grey			blue		blue	
	adult		grey				grey				blue		
Ch fuscofemorata	adult						grey						
C. augur	imm.									grey/blue			blue
	adult	blue											
C. stygia	imm.										blue		
	adult										blue		
C. fulvicoxa	adult										blue		
C. fuscofemorata	adult										blue		
C. centralis	adult										blue		
C. hilli	adult										blue		
C. ochracea	imm.							grey		blue			
H. ligurriens	imm.							grey					
	adult		grey										
L. cuprina	imm.	grey	grey					grey		grey			grey
	adult						grey				blue		
L. papuensis	adult	grey											
S. crassipalpis	imm.		grey				grey			grey			grey
S. impatiens	imm.	grey					grey				blue		blue
	adult	blue											
S. praedatrix	imm.						grey						blue
	adult	blue											
S. aurifrons	imm.						grey						
H. chalcogaster	imm.		grey						blue				
	adult	grey			blue						blue		
S. nudiseta	imm.	grey											
Megaselia sp.	imm.							grey					
	adult	grey	grey			grey	grey						grey
Sepsidae sp.	adult			grey									

environments, with *S. crassipalpis* being collected from 50% of the indoors cases.

Sarcophaga impatiens (active in spring, autumn, winter) was collected from both indoor and outdoor environments, and they were regularly collected during the concurrent insect succession study on the Darling Downs [35]. In one mortuary case, *S. impatiens* and *S. crassipalpis* were the only two species present, suggesting a primary colonisation. In a further three cases, *S. impatiens* probably behaved as a secondary coloniser, arriving after *Ch. megacephala*, *Ch. saffranea*, *C. ochracea*, *L. cuprina*, *H. ligurriens* and *Megaselia* sp. In these cases, the few *S. impatiens* larvae found were younger than other species present.

In all cases that involved sarcophagids, very few individuals were found. This may be that as ovoviviparous flies, they are out-competed by the calliphorids, which have the capacity to produce large numbers of eggs and larvae. The predatory behaviour of *Ch. rufifacies* larvae may also affect sarcophagid survival in carrion.

Large numbers of *Megaselia* sp. were collected as pupae from the skin and clothing of four indoors cases, while 2 adults were collected from the body bag of one outdoors case. These limited collections indicate a distinct preference for indoors locations, and could possibly serve as a useful indication that a corpse has been moved from an indoors location sometime after death.

In the case where *T. zealandicus* was collected from remains found indoors in summer, they had colonised *Ch. megacephala* or *L. cuprina* (records inconclusive), both species having been collected as 2nd instar larvae. In the case where *T. zealandicus* were collected from indoor remains during winter, they had colonised *H. ligurriens*, collected as 2nd and 3rd instar larvae. A parasitised puparium was retained with the wasps and used for identification of the host species [42]. While the literature describing preferred hosts for *T. zealandicus* is sparse, *H. ligurriens* has not been mentioned before as a known host species (S. Voss pers comm).

5. Conclusion

The predominance of Calliphoridae, which were present in 15 of the 20 mortuary cases and all of the road-kill and farmed animal remains, reflects the family's close association with human and other vertebrate remains, justifying the ongoing use of blowflies in forensic investigations. Sarcophagid species were collected from 9 of the 20 mortuary cases, and in three of these cases, were the only larvae present, indicating a potential for *S. crassipalpis* and *S. impatiens* to behave as primary invaders. They appeared to behave as secondary invaders in other cases where much more developmentally advanced Calliphorid larvae were also present.

The conclusion drawn from these results is that the same forensically important insects collected from non-human vertebrate (road-kill and farmed animal) remains are likely to be found at crime scenes involving human remains in the same season and same geographical region. The best forensic indicator species for Qld are likely to be *Ch. rufifacies*, *Ch. megacephala*, *Ch. saffranea*, *Ch. nigripes* and *S. crassipalpis*.

Taxa collected from human remains in south-east Qld are comparable on a species level to those collected from experimental pig carcasses, road-kill and dead farm animals in the same region and during the same seasons. Thus, it is reasonable to assume that pigs remain a useful human model for forensic entomology research. There should soon be opportunities to compare and test the validity of entomological data generated on non-human models with the recent opening of a 'body farm' west of Sydney in NSW, being managed by the University of Technology, Sydney (UTS) http://www.abc.net.au/news/2014-11-19/body-farm-to-study-decomposing-human-corpses-set-up-in-sydney/5904394.

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