Systematics and Thermobiology of Carrion-breeding Blowflies (Diptera: Calliphoridae)

by

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Chapter 2

Molecular Systematics and Identification of *Calliphora* Species

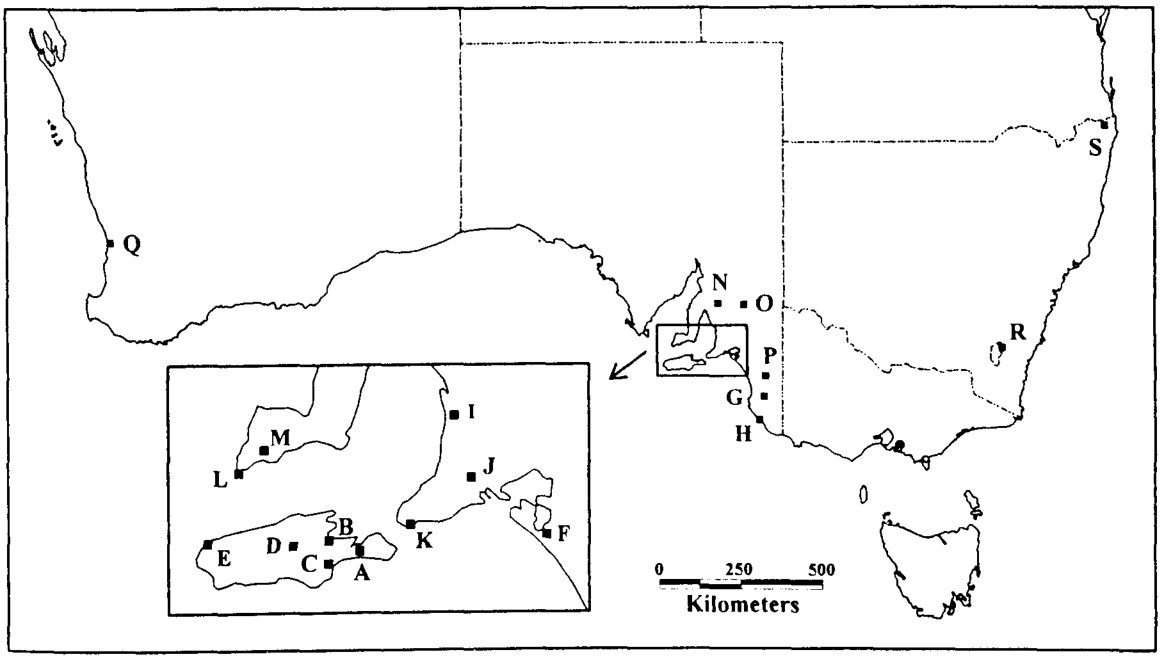


Fig. 2.1. Map showing localities where blowflies were collected in southern Australia. A = Dudley Conservation Park, Kangaroo Island, S.A. (35°48'S, 137°51'E); B = Napean Bay, Kangaroo Island, S.A. (35°44'S, 137°36'E); C = Murray Lagoon, Kangaroo Island, S.A. (35°53'S, 137°26'E); D = Parndana, Kangaroo Island, S.A. (35°46'S, 137°19'E); E = Harvey's Return, Kangaroo Island, S.A. (35°45'S, 136°38'E); F = Meningie, S.A. (35°42'S, 139°20'E); G = Cooranga Homestead, S.A. (36°50'S, 140°18'E); H = Cape Buffon, Canunda National Park, S.A. (37°34'S, 140°07'E); I = Adelaide, S.A. (34°56'S, 138°36'E); J = Cox Scrub Conservation Park, S.A. (35°20'S, 138°44'E); K = Deep Creek Conservation Park, S.A. (35°38'S, 138°15'E) ; L = Cape Spencer, Innes National Park, S.A. (35°18'S, 136°53'E); M = Warrenben Conservation Park, S.A. (35°09'S, 137°05'E); N = Spring Gully Conservation Park, S.A. (33°55'S, 138°36'E); O = Whites Dam Conservation Park, S.A. (33°57'S, 139°33'E); P = Mount Monster Conservation Park, S.A. (36°12'S, 140°20'E); Q = Perth, W.A. (31°57'S, 115°51'E); R = Canberra, A.C.T. (35°17'S, 149°13'E); S = Bar Mountain, Border Ranges National Park, N.S.W. (28°28'S, 153°08'E).

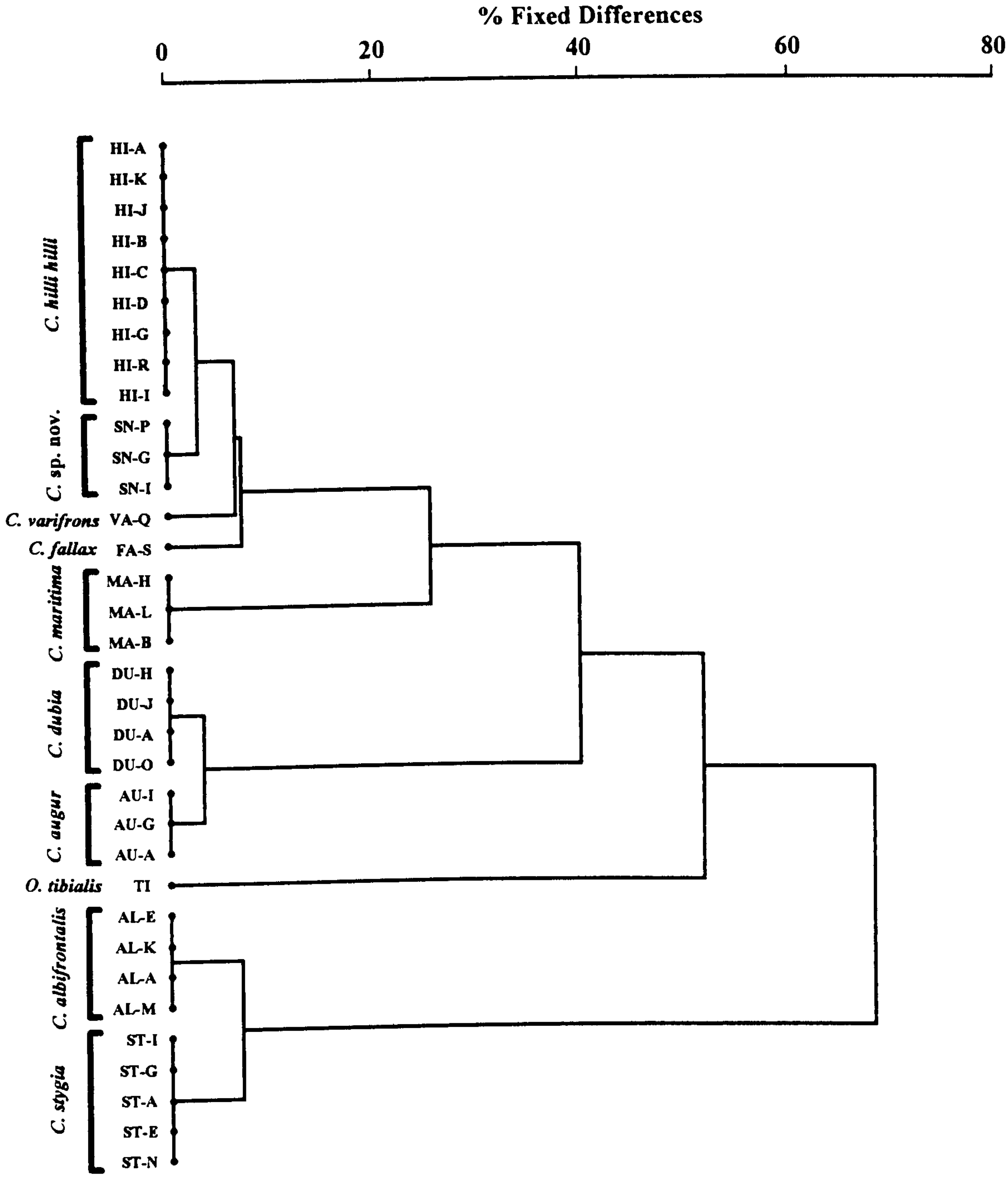


Fig. 2.2. UPGMA phenogram depicting the genetic relationships among populations and taxa sampled in the overview study. The two specimens of *O. tibialis* (TI-G and TI-J) were treated as a single population.

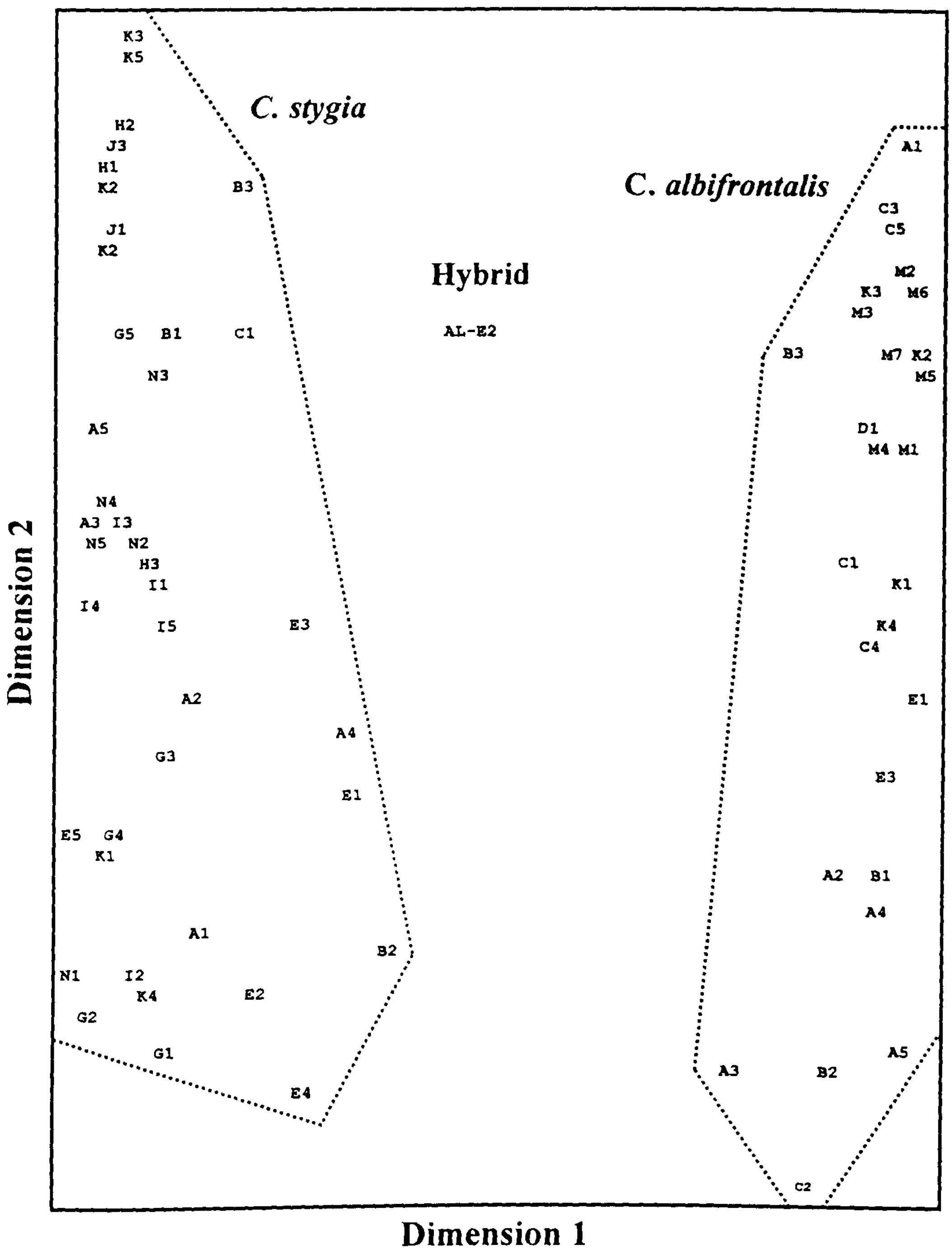


Fig. 2.3. Plot of the PCoA scores within the first two dimensions for *C. stygia* and *C. albifrontalis* (data taken from Table 2.4). Individuals are identified by locality and number only (except for AL-E2). The first dimension accounts for 38% of the variability, while the second dimension accounts for a further 12%.

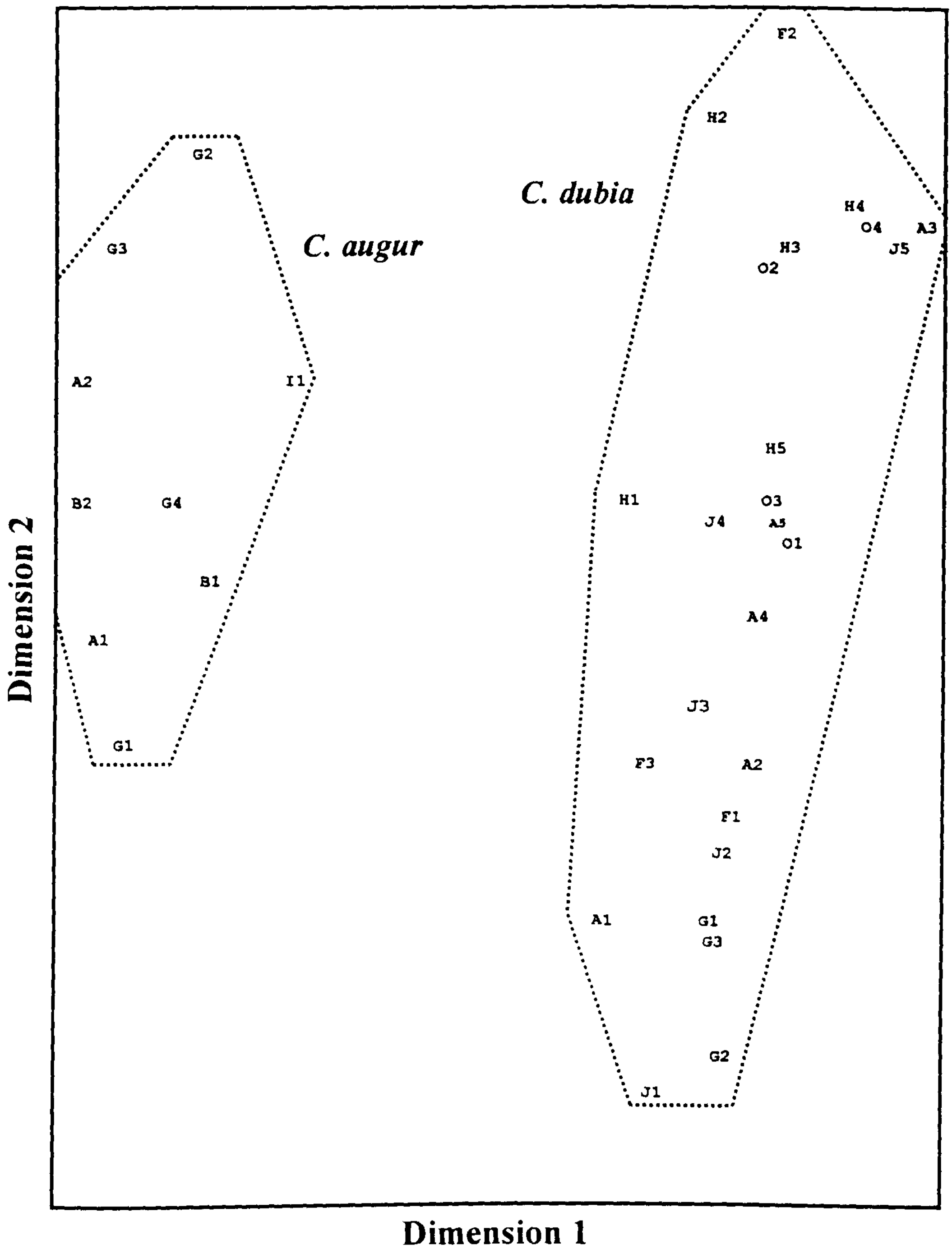


Fig 2.4. Plot of the PCoA score within the first two dimensions for *C. dubia* and *C. augur* (data taken from Table 2.6). Format as for Fig. 2.3. The first dimension accounts for 20% of the variability, while the second dimension accounts for a further 12%.

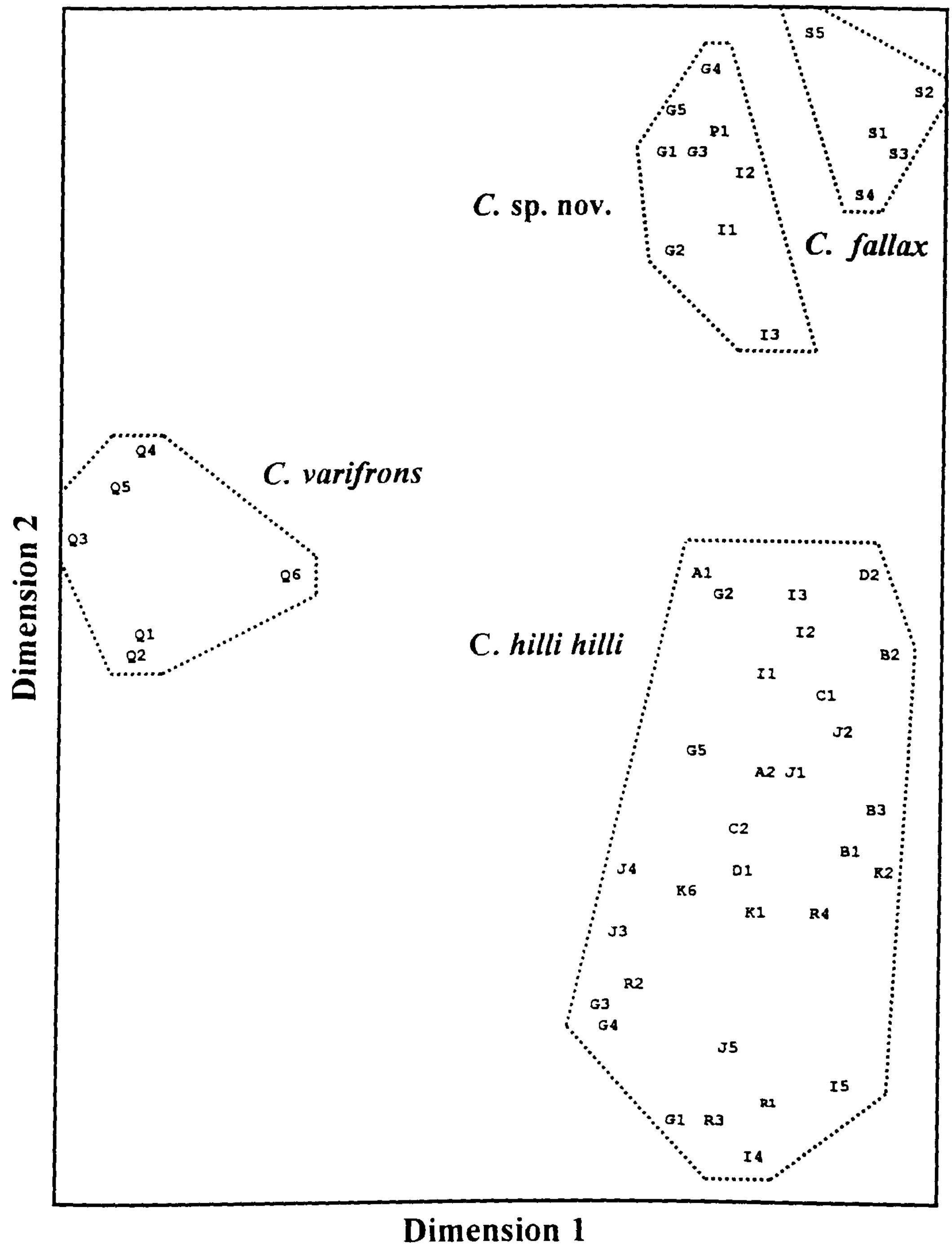


Fig. 2.5. Plot of the PCoA score within the first two dimensions for members of the *C. hilli*-group (data taken from Table 2.3 for loci polymorphic within the group). Format as for Fig. 2.3. The first dimension accounts for 18% of the variability, while the second dimension accounts for a further 13%.

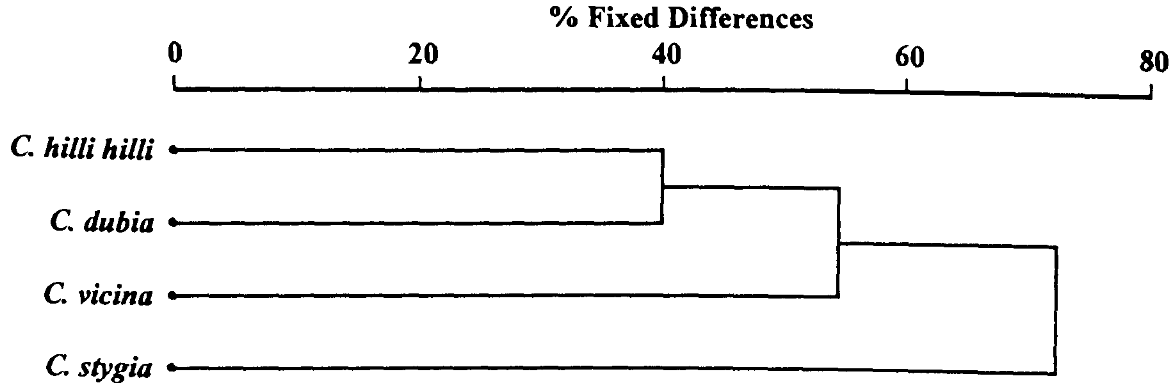


Fig. 2.6. UPGMA phenogram depicting the genetic relationships among taxa sampled in the study on the molecular identification of larvae. To make genetic distances comparable with those shown in Fig. 2.2, the same 35 loci used in that study were analysed for the production of this figure, even though some of them were invariant in the present work.

Table 2.1. Summary of collecting localities and associated sample sizes. The code assigned to each species is that used in Tables 2.3, 2.4 and 2.6. Locality codes are as in Fig. 2.1. The sample sizes for each taxon at each locality are given in brackets, with the first number referring to the specimens analysed in the overview study and the second number, where present, indicating extra samples run only for the polymorphic loci.

Taxon	Species Code	Locality/Sample Sizes
C. stygia	ST	A (2+3), B (0+3), C (0+1), E (2+3), G (2+3), H (0+3), I (2+3), J (0+3), K (0+5), N (2+3)
C. albifrontalis	AL	A (2+3), B (0+3), C (0+5), D (0+1), E (2+1), K (2+2), M (2+5)
C. dubia	DU	A (2+3), F (0+3), G (0+3), H (2+3), J (2+3), O (2+2)
C. augur	AU	A (2), B (0+2), G (2+2), I (1)
C. hilli hilli	HI	A (2), B (3), C (2), D (2), G (5), I (5), J (6), K (2), R (4)
C. fallax	FA	S (5)
C. varifrons	VA	Q (6)
C. maritima	MA	B (1), H (5), L (2)
C. sp. nov.	SN	G (5), I (3), P (1)
O. tibialis	TI	G (1), J (1)

Table 2.2. Summary of the electrophoretic methods employed for each allozyme marker. [1]The buffer codes refer to those used by Richardson *et al.* (1986). [2]Codes for stain recipes:- 1 - Richardson *et al.* (1986); 2 - Lanser *et al.* (1990); 3 - Manchenko (1984), but without the agarose and scaled down to 2 mls final volume; 4 - as for AK stain in Richardson *et al.* (1986) with the addition of 6 mg GTP.

Enzyme Abbrev.	Common name	E.C. No.	Marker	Buffer[1]	Run Time (mins)	Stain[2]
ACON	aconitate hydratase	4.2.1.3	*Acon-1,Acon-2, Acon-3*	all on B	120	1
ACP	acid phosphatase	3.1.3.2	*Acp*	D	140	1 - method A
ACYC	acyclase	3.5.1.14	*Acyc*	C	165	2
ARGK	arginine kinase	2.7.3.3	*Argk*	B	120	3 - method 2
DIA	diaphorase	1.6.99.?	*Dia*	B	120	1 - no MTT
ENOL	enolase	4.2.1.11	*Enol*	A	120	1
EST	esterase	3.1.1.?	*Est-1,Est-2*	C	110	1 - method A
FUM	fumarate hydratase	4.2.1.2	*Fum*	B	140	1
GDA	guanine deaminase	3.5.4.3	*Gda*	B	140	1
GLDH	glucose dehydrogenase	1.1.1.47	*Gldh*	B	150	1
GOT	aspartate aminotransferase	2.6.1.1	*Got-1,Got-2*	B	150	1
GPI	glucose-phospate isomerase	5.3.1.9	*Gpi*	B	140	1
HEX	hexosaminidase	3.2.1.30	*Hex*	C	135	3 - method 1
HK	hexokinase	2.7.1.1	*Hk-1,Hk-2*	D	165	1
IDH	isocitrate dehydrogenase	1.1.1.42	*Idh*	A	120	1
MDH	malate dehrdrogenase	1.1.1.37	*Mdh-1,Mdh-2*	B	140	1
ME	malic enzyme	1.1.1.40	*Me-1*	B	85	1
			Me-2	D	135	1
MPI	mannose-phosphate isomerase	5.3.1.8	*Mpi*	B	150	1
NDPK	nucleoside diphosphate kinase	2.7.4.6	*Ndpk*	B	140	4
PEPA	dipeptidase (val-leu)	3.4.13.?	*PepA*	C	140	1
PEPB	tripeptide aminopeptidase (leu-gly-gly)	3.4.11.?	*PepB*	C	140	1
PEPD	proline dipeptidase (phe-pro)	3.4.13.?	*PepD-1,PepD-2*	C	150	1
PEPS	dipeptidase (lys-leu)	3.4.13.?	*PepS*	C	150	1 - PEPC stain
PGAM	phosphoglycerate mutase	4.2.4.1	*Pgam*	B	120	1
PGM	phosphoglucomutase	5.4.2.2	*Pgm*	C	150	1
SORDH	L-iditol (sorbitol) dehydrogenase	1.1.1.14	*Sordh*	C	150	1
TPI	triose-phosphate isomerase	5.3.1.1	*Tpi-1,Tpi-2*	B	140	1

Table 2.3. Allozyme profiles at the 32 loci found to be variable in the overview study. Allozymes are designated alphabetically (a - the most cathodally migrating). Individuals are listed numerically by taxon (codes as in Table 2.1) and locality (codes as in Fig. 2.1), e.g. ST-A1 and ST-A2 are the two *C. stygia* from locality A. Codes for loci: 1 = *Acon-1*, 2 = *Acon-2*, 3 = *Acon-3*, 4 = *Acp*, 5 = *Acyc*, 6 = *Argk*, 7 = *Dia*, 8 = *Enol*, 9 = *Est*, 10 = *Gda*, 11 = *Gldh*, 12 = *Got-1*, 13 = *Got-2*, 14 = *Gpi*, 15 = *Hex*, 16 = *Hk-1*, 17 = *Idh*, 18 = *Mdh-2*, 19 = *Me-1*, 20 = *Me-2*, 21 = *Mpi*, 22 = *Ndpk*, 23 = *PepA*, 24 = *PepB*, 25 = *PepD-1*, 26 = *PepD-2*, 27 = *PepS*, 28 = *Pgam*, 29 = *Pgm*, 30 = *Sordh*, 31 = *Tpi-2*. A hyphen indicates that the locus could not be scored in this individual.

Individual	Locus																													
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
ST-A1	b	a	c	b	e	b	f	a	a	c	e	a	a	a	e	d	b	a	a	d	b	a	e	be	e	e	b	b	ab	b	a
ST-A2	b	a	c	b	e	b	f	a	a	c	e	a	a	a	e	d	b	a	a	d	ae	-	e	e	e	e	b	b	a	b	a
ST-E1	b	a	c	b	eg	b	f	a	a	c	e	a	a	a	e	d	b	a	a	de	bf	a	e	be	e	e	b	b	a	b	a
ST-E2	b	a	c	b	eg	b	f	a	a	cd	e	a	a	a	e	d	b	a	a	d	ab	a	e	de	e	e	b	b	ab	b	a
ST-G1	b	a	c	b	eg	b	f	a	a	bc	e	-	a	a	e	d	b	a	a	d	af	a	e	e	e	e	b	b	b	b	a
ST-G2	b	a	c	b	g	b	f	a	a	c	e	a	a	a	e	d	b	a	a	d	b	-	e	e	e	e	b	b	ab	b	a
ST-I1	b	a	c	b	e	b	f	a	a	d	e	a	a	a	e	d	b	a	a	d	ab	a	e	e	e	e	b	b	a	b	a
ST-I2	b	a	c	b	e	b	f	a	a	c	e	-	a	a	e	d	b	a	a	d	be	-	e	e	e	e	b	b	ab	ab	a
ST-N1	b	a	c	b	e	b	f	a	a	c	e	a	a	a	e	d	b	a	a	d	b	a	e	e	e	e	bc	b	b	b	a
ST-N2	b	a	c	b	eg	b	f	a	a	cd	e	a	a	a	e	d	ab	a	a	d	b	a	e	e	e	e	b	b	a	b	a
AL-A1	b	a	c	b	e	b	f	a	a	cd	f	a	a	a	e	d	b	a	a	e	i	-	e	b	e	g	b	b	a	b	a
AL-A2	b	a	c	b	e	b	f	a	a	bd	e	a	a	a	e	d	b	a	a	e	fi	a	e	b	e	g	b	b	ab	ab	a
AL-E1	b	a	c	b	eg	b	f	a	a	cg	e	-	a	a	e	d	b	a	a	e	i	-	e	b	e	g	b	b	a	b	a
AL-E2	b	a	c	b	e	b	f	a	a	c	ef	a	-	a	e	d	b	a	a	de	bf	a	e	be	e	eg	bc	b	a	b	a
AL-K1	b	a	c	b	e	b	f	a	a	bd	e	a	a	a	e	d	b	a	a	e	i	a	e	b	e	g	b	b	a	-	a
AL-K2	b	a	c	b	eg	b	ef	a	a	c	f	a	a	a	e	d	b	a	a	e	i	a	e	b	e	g	b	b	a	-	a
AL-M1	b	a	c	b	eg	b	f	a	a	c	ef	a	a	a	e	d	b	a	a	e	i	a	e	b	e	g	b	b	a	b	a
AL-M2	b	a	c	b	e	b	f	a	a	cg	f	a	a	a	e	d	b	a	a	e	fi	a	e	b	e	g	b	b	a	b	a
DU-A1	a	b	cd	a	e	b	c	c	c	ad	cf	c	a	c	d	bc	c	b	d	e	gj	b	g	c	f	d	k	b	de	a	b
DU-A2	a	b	d	a	eg	b	c	c	c	-	c	c	a	c	d	b	c	b	d	e	hj	b	g	c	f	d	k	b	df	ab	b
DU-H1	a	b	d	a	eh	b	ac	c	c	d	c	c	a	c	d	b	c	b	d	e	j	b	g	c	f	d	k	b	e	a	b
DU-H2	a	b	d	a	de	b	c	c	c	cd	c	c	ac	c	de	b	c	b	d	e	gl	b	fg	c	f	d	k	b	e	a	b
DU-J1	a	b	cd	a	e	b	bc	c	c	cd	cf	c	a	c	d	bc	c	b	d	e	j	b	g	c	f	d	k	b	ce	a	b
DU-J2	a	-	-	a	de	b	-	c	c	-	cf	c	a	c	d	-	-	b	d	e	kl	b	g	c	f	d	k	b	de	ab	b
DU-O1	a	b	d	a	eg	b	c	c	c	cd	bc	c	a	c	d	b	c	b	d	e	gl	b	g	ac	f	d	k	b	e	a	b
DU-O2	a	ab	d	a	eg	b	c	c	cd	d	cf	c	a	c	d	bc	c	b	d	e	jk	b	gh	c	f	d	k	b	e	-	b
AU-A1	a	b	d	a	ce	b	c	c	c	dg	cf	c	a	c	de	bc	c	b	d	e	gj	b	g	c	ef	a	k	b	ce	a	b
AU-A2	a	ab	d	a	ce	b	c	c	c	d	c	-	a	c	d	c	c	b	d	e	gj	b	g	c	f	a	k	b	ef	ab	b
AU-G1	a	b	d	a	e	b	c	c	c	dk	cf	c	a	c	d	bc	c	b	d	e	gj	b	g	c	f	a	k	b	ef	a	b
AU-G2	a	b	d	a	eg	b	c	c	c	d	bc	c	ac	c	d	bd	c	b	d	e	fg	b	g	c	f	a	k	b	e	a	b
AU-I1	a	ab	d	a	e	b	c	c	c	de	cf	c	-	c	d	ac	c	b	d	e	gj	b	fg	c	f	a	k	b	e	ab	b
HI-A1	a	a	d	a	ce	b	c	b	b	gk	b	c	c	c	b	bc	c	a	cd	b	f	b	d	c	d	f	e	b	c	a	b
HI-A2	a	a	d	a	ce	b	c	b	bc	k	b	c	-	c	b	-	c	a	cd	b	f	b	cd	c	d	f	e	b	c	a	b
HI-B1	a	a	d	a	be	b	c	b	b	ik	b	c	c	c	b	b	c	a	c	b	df	b	cd	ac	bd	f	e	b	c	a	b
HI-B2	a	a	d	a	e	b	c	b	b	k	b	c	ac	c	b	b	c	a	c	b	fh	b	d	c	d	f	e	b	c	a	b
HI-B3	-	a	d	a	e	b	c	b	b	hk	b	c	-	c	b	-	c	a	c	b	df	b	cd	c	d	f	e	b	c	a	b
HI-C1	a	a	d	a	ce	b	c	b	b	ik	bd	c	-	c	b	b	c	a	c	b	f	b	d	c	d	f	e	b	c	a	b
HI-C2	a	a	d	a	e	b	c	b	b	ik	b	c	ac	c	b	c	c	a	cd	b	df	b	cd	c	d	f	e	b	c	a	b
HI-D1	a	a	d	a	ce	b	c	b	b	ik	ab	c	c	c	bc	bc	c	a	c	b	f	b	d	ac	d	f	e	b	c	a	b
HI-D2	a	a	d	a	e	b	c	b	b	hk	be	c	c	c	b	b	c	a	c	b	f	b	d	c	d	f	eh	b	c	a	b
HI-G1	a	a	d	a	g	b	ce	b	b	k	b	c	c	c	b	c	c	ac	c	b	df	b	d	c	bd	f	e	b	c	a	b
HI-G2	a	a	d	a	e	b	ce	b	b	ik	b	c	c	c	b	bd	c	ac	cd	b	f	b	d	c	d	f	e	b	c	a	bc
HI-G3	a	a	d	a	ac	b	ce	b	b	k	b	c	c	c	b	c	c	ac	cd	b	df	b	d	c	bd	f	e	b	c	a	b
HI-G4	a	a	d	a	c	b	ac	b	b	gk	b	c	c	c	b	c	c	a	c	b	f	b	cd	c	bd	f	e	b	c	a	b
HI-G5	-	-	d	a	eg	b	c	b	b	ik	d	c	ac	c	b	cd	c	a	c	b	df	-	d	c	d	f	e	b	c	a	b
HI-I1	a	a	d	a	e	b	ce	b	bc	gk	b	c	c	c	b	b	c	ac	c	b	f	b	d	bc	bd	f	e	b	c	a	b
HI-I2	a	a	d	a	e	b	ce	b	bc	gh	b	c	d	c	b	b	c	a	c	b	f	b	d	ac	bd	f	ei	b	c	a	b
HI-I3	a	a	d	a	eg	b	c	b	b	gk	b	c	cd	c	b	b	c	ac	cd	b	f	b	d	c	bd	f	e	b	c	a	b
HI-I4	a	-	d	a	ch	-	c	b	-	ik	b	c	-	c	b	cd	c	a	c	b	f	b	d	c	bd	f	e	-	c	-	b
HI-I5	a	-	d	a	eg	-	c	b	-	k	b	c	-	c	b	bc	c	a	c	b	f	b	d	c	bd	f	ei	-	c	-	b

Table 2.3. Continued.

Individual	Locus 1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31
HI-J1	a	a	d	a	e	b	c	b	b	k	b	c	c	c	b	cd	c	a	bc	b	f	b	ad	ac	d	f	ef	b	c	a	b
HI-J2	a	a	d	a	eg	b	c	b	b	i	b	c	c	c	b	bd	ce	a	c	b	f	b	cd	c	d	f	e	b	c	a	b
HI-J3	a	a	d	a	c	b	c	b	b	k	b	c	c	c	b	c	c	a	cd	b	f	b	d	ac	d	f	ej	ab	c	a	b
HI-J4	a	a	d	a	ce	b	ac	b	b	i	b	c	c	c	b	c	c	a	c	b	f	b	bd	c	d	f	de	b	c	a	b
HI-J5	a	a	d	a	c	b	c	b	b	k	b	c	c	c	b	bc	c	a	c	b	f	b	d	c	bd	f	e	b	c	a	b
HI-J6	a	a	d	a	ac	b	c	b	b	ik	b	c	c	c	c	c	c	a	cd	b	df	b	cd	c	d	f	e	b	c	a	b
HI-K1	a	a	d	a	c	b	c	b	b	ik	b	c	-	c	b	bc	c	a	c	b	f	b	d	c	d	f	e	b	c	a	b
HI-K2	a	a	d	a	e	b	c	b	b	k	bd	c	c	c	b	d	c	a	c	b	f	b	cd	c	d	f	i	b	c	a	b
HI-R1	a	a	d	a	cg	b	c	b	b	ik	b	c	c	c	b	ce	c	ac	c	b	f	b	cd	c	bd	f	e	b	bc	a	b
HI-R2	a	a	d	a	c	b	c	b	b	ik	b	c	c	c	b	c	c	a	bc	b	f	b	d	c	bd	f	e	b	c	a	b
HI-R3	a	a	d	a	eg	b	c	b	b	k	b	c	c	c	b	c	c	ac	c	ab	f	b	d	c	bd	f	e	b	c	a	b
HI-R4	a	a	d	a	ce	b	c	b	b	k	b	c	c	c	b	bc	c	ac	c	b	df	b	bd	c	d	f	e	b	c	a	b
SN-G1	a	a	d	a	eg	b	ce	b	b	g	b	c	c	c	b	b	c	a	d	b	f	b	d	c	ad	f	e	b	c	a	b
SN-G2	a	a	d	a	c	b	c	b	b	dg	b	c	c	c	b	b	c	a	d	b	f	b	d	bc	d	fh	e	b	c	a	b
SN-G3	ac	a	d	a	ce	b	ce	b	b	eg	b	c	c	c	b	b	c	c	d	b	f	b	d	c	d	f	eh	b	c	a	b
SN-G4	a	a	d	a	e	b	ce	b	b	g	b	c	c	c	b	b	c	a	d	b	f	b	d	c	d	f	e	b	c	a	b
SN-G5	a	a	bd	a	ce	b	c	b	b	g	b	c	c	c	b	b	c	a	d	b	f	b	d	c	d	f	e	b	c	a	b
SN-I1	a	a	d	a	e	b	e	b	b	g	b	c	c	c	b	b	ac	ac	cd	b	f	b	d	c	d	f	e	b	c	a	b
SN-I2	a	a	d	a	eg	b	c	b	b	g	b	c	c	c	b	ab	c	a	d	b	f	b	d	c	d	f	eg	b	c	a	b
SN-I3	a	-	d	a	cg	-	c	b	-	-	b	c	-	c	b	b	c	ac	d	b	f	b	d	c	d	f	e	-	c	-	b
SN-P1	a	a	d	a	ce	b	c	b	b	g	b	c	c	c	b	b	c	a	d	b	f	b	d	c	d	f	e	b	c	a	b
FA-S1	a	a	d	a	ce	b	c	b	b	dg	b	c	c	c	b	b	c	a	b	b	h	b	bc	c	d	f	e	b	c	a	b
FA-S2	a	a	d	a	g	b	c	b	b	dg	b	c	c	c	b	b	c	a	b	b	h	b	c	c	d	f	eg	b	c	a	b
FA-S3	a	ab	d	a	e	b	c	b	b	g	b	c	c	c	b	bc	c	a	b	b	h	b	cd	c	d	f	eg	b	c	a	b
FA-S4	a	a	d	a	ce	b	c	b	b	cg	b	c	c	c	b	ab	c	a	b	ab	h	b	cd	c	d	f	eg	b	c	a	b
FA-S5	a	a	d	a	e	b	c	b	b	g	b	c	c	cd	b	b	c	a	b	b	h	b	d	c	cd	f	e	b	c	a	b
VA-Q1	a	a	cd	ac	ce	b	a	b	b	fj	b	c	c	c	b	c	c	a	cd	b	f	b	d	ce	cd	f	e	b	c	a	b
VA-Q2	a	a	cd	ac	ce	b	a	b	b	fj	b	c	c	c	b	c	c	a	cd	b	f	b	d	ce	c	f	e	b	c	a	b
VA-Q3	a	a	c	c	c	b	a	b	bd	f	b	c	c	c	b	c	c	a	d	b	f	b	d	ce	cd	f	e	b	c	a	b
VA-Q4	a	a	cd	c	ce	b	a	b	b	fj	b	c	c	c	b	c	c	a	d	b	cf	b	d	c	cd	f	e	b	c	a	b
VA-Q5	a	a	cd	ac	ce	b	a	b	b	fj	b	c	c	c	b	c	c	a	d	b	f	b	d	ce	cd	f	e	b	c	a	b
VA-Q6	a	a	cd	ac	e	b	a	b	b	fj	b	c	c	c	b	c	c	a	cd	b	f	b	d	c	d	f	e	b	c	a	b
MA-B1	a	a	ac	a	c	b	a	b	b	g	b	bc	-	a	b	b	c	a	b	c	f	b	c	c	e	b	g	b	ce	a	b
MA-H1	a	a	ac	a	c	b	a	b	b	d	b	c	-	a	bc	b	cd	a	b	c	f	b	c	c	e	b	g	b	c	a	b
MA-H2	a	a	a	a	c	b	a	b	b	dg	b	c	-	a	b	b	c	a	b	c	f	b	c	c	e	b	g	b	c	a	b
MA-H3	a	a	ac	a	c	b	a	b	b	g	b	c	a	a	b	b	c	a	b	c	f	b	c	c	e	b	g	b	c	a	b
MA-H4	a	a	ac	a	c	b	a	b	b	g	b	cd	a	a	ab	b	c	a	b	c	cf	b	c	c	e	b	g	b	c	a	b
MA-H5	a	a	a	a	ac	b	a	b	b	g	b	c	a	a	bc	b	c	a	-	c	f	b	c	c	e	b	eg	b	c	a	b
MA-L1	a	a	c	a	c	b	a	b	b	g	b	c	a	a	ab	b	c	a	b	c	f	b	c	c	e	b	g	b	c	a	b
MA-L2	a	a	ac	a	c	b	a	b	b	g	b	-	a	a	b	b	c	a	b	c	cf	b	c	c	e	b	g	b	c	a	b
TI-G1	a	a	d	-	f	a	d	b	b	l	g	d	b	b	f	b	bc	a	c	be	g	b	e	c	b	c	a	a	c	c	b
TI-J1	a	a	-	-	f	a	d	b	-	-	g	d	b	b	-	-	c	a	a	e	g	b	e	c	b	c	a	a	c	c	b

Table 2.4. Allozyme profiles at eight polymorphic loci for all *C. albifrontalis* and *C. stygia* individuals. Codes for loci as in Table 2.2.

Individual	Locus							
	5	10	11	21	24	25	26	29
AL-A1	b	de	b	g	a	b	b	a
AL-A2	b	be	a	fg	a	b	b	ab
AL-A3	be	d	a	g	ac	b	b	ab
AL-A4	b	dg	a	g	a	b	b	ab
AL-A5	e	dg	a	g	a	b	b	ab
AL-B1	b	be	a	g	a	b	b	ab
AL-B2	be	d	a	fg	a	b	b	ab
AL-B3	b	d	ab	f	a	b	b	a
AL-C1	b	d	b	fg	a	b	b	ab
AL-C2	e	d	a	fg	a	b	b	b
AL-C3	b	de	ab	g	a	b	b	a
AL-C4	b	df	a	g	a	b	b	a
AL-C5	b	de	ab	g	a	b	b	a
AL-D1	be	d	ab	fg	a	ab	b	a
AL-E1	be	dg	a	g	a	b	b	a
AL-E2	b	d	ab	cf	ac	b	ab	a
AL-E3	be	d	a	g	a	b	b	a
AL-K1	b	be	a	g	a	b	b	a
AL-K2	be	d	b	g	a	b	b	a
AL-K3	b	dg	ab	fg	a	b	b	a
AL-K4	b	cd	a	g	a	b	b	a
AL-M1	be	d	ab	g	a	b	b	a
AL-M2	be	dg	b	fg	a	b	b	a
AL-M3	ce	de	ab	fg	a	b	b	a
AL-M4	b	ad	ab	g	a	b	b	ac
AL-M5	be	bd	ab	g	a	b	b	a
AL-M6	b	dg	ab	g	a	b	b	a
AL-M7	be	bd	bd	fg	a	b	b	a
ST-A1	b	d	a	c	ac	b	a	ab
ST-A2	b	d	a	bd	c	b	a	a
ST-A3	b	df	a	c	c	b	a	a
ST-A4	be	df	a	ab	ac	b	a	a
ST-A5	b	cf	ab	c	c	ab	a	ab
ST-B1	b	d	ab	bc	c	b	a	a
ST-B2	b	d	a	ce	a	b	a	-
ST-B3	bd	de	ab	c	ac	b	a	a
ST-C1	b	de	ac	c	ac	b	a	a
ST-E1	be	d	a	ce	ac	b	a	a
ST-E2	be	df	a	bc	bc	b	a	ab
ST-E3	be	de	ab	ce	ac	b	a	ab
ST-E4	bd	d	a	e	ac	b	a	ab
ST-E5	b	de	a	c	c	b	a	b
ST-G1	bd	cd	a	be	c	b	a	b
ST-G2	e	d	a	c	c	b	a	ab
ST-G3	be	d	a	ce	c	b	a	a
ST-G4	be	de	a	c	c	b	a	ab
ST-G5	be	d	ab	c	c	b	a	a
ST-H1	b	df	ab	c	c	b	a	a
ST-H2	bf	eg	ab	c	c	b	a	a
ST-H3	b	df	ab	ce	c	b	a	ab
ST-I1	b	f	a	bc	c	b	a	a
ST-I2	b	d	a	ce	c	b	a	ab
ST-I3	b	df	a	c	c	b	a	a
ST-I4	b	d	a	c	c	b	a	a
ST-I5	b	d	a	c	cd	b	a	a
ST-J1	ef	cd	ab	c	c	b	a	a
ST-J2	b	cd	ab	c	c	b	a	a
ST-J3	ab	de	ab	c	c	b	a	a
ST-K1	e	d	ac	c	c	b	a	ab
ST-K2	b	d	ab	c	c	b	a	a
ST-K3	bd	e	b	c	c	b	a	a
ST-K4	b	d	a	bc	c	b	a	bc
ST-K5	b	de	b	c	c	b	a	a
ST-N1	b	d	a	c	c	b	a	b
ST-N2	be	de	a	c	c	b	a	a
ST-N3	bf	d	ab	ce	c	b	a	a
ST-N4	bc	d	ab	cd	c	b	a	-
ST-N5	b	d	ab	c	c	b	a	ab

Table 2.5. Allozyme frequencies for the three PCoA clusters defined within the *C. stygia*-group. The frequency of each allozyme is expressed as a percentage and shown as a superscript.

Locus	*C. albifrontalis*	AL-E2	*C. stygia*
Acyc	b^{70},e^{28},c^{2}	b	$b^{73},e^{16},d^{5},f^{4},a^{1},c^{1}$
Gda	$d^{61},e^{13},g^{11},b^{9},a^{2},c^{2},f^{2}$	d	$d^{69},e^{14},f^{11}, c^{5},g^{1}$
Gldh	a^{63},b^{35},d^{2}	ab	a^{74},b^{24},c^{2}
Mpi	g^{80},f^{20}	cf	$c^{75},e^{12},b^{9},d^{3},a^{1}$
PepB	a^{98},c^{2}	ac	$c^{87},a^{11},b^{1},d^{1}$
PepD-1	b^{98},a^{2}	b	b^{99},a^{1}
PepD-2	b	ab	a
Pgm	a^{81},b^{17},c^{2}	a	a^{75},b^{24},c^{1}

Table 2.6. Allozyme profiles at eight polymorphic loci for all *C. augur* and *C. dubia* individuals. Codes for loci as in Table 2.2.

Individual	Locus							
	5	10	11	21	23	25	26	29
AU-A1	ab	hk	bc	ce	b	ab	a	ac
AU-A2	ab	h	b	ce	b	b	a	cd
AU-B1	b	bh	bc	bc	b	b	a	c
AU-B2	-	h	c	eg	b	bc	a	ac
AU-G1	b	hm	bc	ce	b	b	a	cd
AU-G2	bc	h	ab	bc	b	b	a	c
AU-G3	ab	h	ab	ce	b	b	a	c
AU-G4	b	h	b	e	b	b	a	c
AU-I1	b	hj	bc	ce	ab	b	a	c
DU-A1	b	ah	bc	ce	b	b	b	bc
DU-A2	bc	df	b	de	b	b	b	bd
DU-A3	ac	f	bc	cf	ab	b	b	c
DU-A4	bc	hi	bc	e	b	b	b	c
DU-A5	b	df	b	ce	ab	b	b	c
DU-F1	b	cl	bc	cg	b	b	b	c
DU-F2	ac	h	bc	ac	ab	b	b	c
DU-F3	b	fh	bc	ce	b	b	b	c
DU-G1	b	g	b	e	b	b	b	c
DU-G2	b	gk	bc	fg	b	b	b	bc
DU-G3	b	gi	c	e	b	b	b	c
DU-H1	bd	h	b	e	b	b	b	c
DU-H2	ab	h	b	cg	ab	b	b	c
DU-H3	bc	h	bc	e	ab	b	b	c
DU-H4	bc	hi	ab	ef	ab	b	b	c
DU-H5	b	hl	bc	c	ab	b	b	c
DU-J1	b	eg	bc	e	b	b	b	ac
DU-J2	ab	kl	bc	fg	b	b	b	bc
DU-J3	c	eh	bc	eg	b	-	b	ac
DU-J4	ab	dh	bc	cg	b	b	b	c
DU-J5	bc	dh	c	df	ab	b	b	c
DU-O1	bc	fg	ab	cg	b	b	b	c
DU-O2	bc	h	bc	ef	bc	b	b	c
DU-O3	bc	fh	b	ae	b	-	b	c
DU-O4	ac	dh	bc	eg	ab	b	b	c

Table 2.7. A comparison between the allozyme frequencies for *C. augur* and *C. dubia* at the eight polymorphic loci. The frequency of each allozyme is expressed as a percentage and shown as a superscript.

Locus	*C. augur*	*C. dubia*
Acyc	b^{75},a^{19},c^{6}	$b^{60},c^{26},a^{12},d^{2}$
Gda	$h^{78},b^{5.5},j^{5.5},k^{5.5},m^{5.5}$	$h^{40},f^{14},g^{12},d^{10},i^{6},l^{6},e^{4},k^{4},a^{2},c^{2}$
Gldh	b^{56},c^{33},a^{11}	b^{58},c^{38},a^{4}
Mpi	$e^{44},c^{39},b^{11},g^{6}$	$e^{42},c^{22},g^{16},f^{12},a^{4},d^{4}$
PepA	b^{94},a^{6}	b^{80},a^{18},c^{2}
PepD-1	b^{89},a^{6},c^{5}	b
PepD-2	a	b
Pgm	c^{78},a^{11},d^{11}	c^{86},b^{8},a^{4},d^{2}

Table 2.8. A comparison between the allozyme frequencies for the members of the *C. hilli*-group at the 26 polymorphic loci. The frequency of each allozyme is expressed as a percentage and shown as a superscript.

Locus	*C. hilli hilli*	*C.* sp. nov.	*C. fallax*	*C. varifrons*
Acon-1	a	a	a^{94},b^{6}	a
Acon-2	a	a	a^{90},b^{10}	a
Acon-3	d	d^{94},b^{6}	d	c^{58},d^{42}
Acp	a	a	a	c^{67},a^{33}
Acyc	$e^{48},c^{32},g^{13},a^{3},b^{2},h^{2}$	e^{50},c^{33},g^{17}	e^{60},c^{20},g^{20}	c^{50},e^{50}
Dia	c^{89},e^{8},a^{3}	c^{72},e^{28}	c	a
Est	b^{95},c^{5}	b	b	b^{92},d^{8}
Gda	$k^{63},i^{24},g^{8},h^{5}$	g^{88},d^{6},e^{6}	g^{70},d^{20},c^{10}	f^{58},j^{42}
Gldh	b^{90},d^{6},a^{2},e^{2}	b	b	b
Got-2	c^{88},a^{6},d^{6}	c	c	c
Gpi	c	c	c^{90},d^{10}	c
Hex	b^{95},c^{5}	b	b	b
Hk-1	$c^{48},b^{38},d^{12},e^{2}$	b^{94},a^{6}	b^{80},a^{10},c^{10}	c
Idh	c^{98},e^{2}	c^{94},a^{6}	c	c
Mdh-2	a^{87},c^{13}	a^{78},c^{22}	a	a
Me-1	c^{84},d^{13},b^{3}	d^{94},c^{6}	b	d^{75},c^{25}
Me-2	b^{98},a^{2}	b	b^{90},a^{10}	b
Mpi	f^{85},d^{13},h^{2}	f	h	f^{98},c^{2}
PepA	$d^{80},c^{15},b^{3},a^{2}$	d	c^{50},d^{40},b^{10}	d
PepB	c^{90},a^{8},b^{2}	c^{94},b^{6}	c	c^{67},e^{33}
PepD-1	d^{79},b^{21}	d^{94},a^{6}	d^{90},c^{10}	c^{50},d^{50}
PepD-2	f	f^{94},h^{6}	f	f
PepS	$e^{87},i^{6},d^{2},f^{2},j^{2},h^{1}$	e^{89},g^{6},h^{5}	e^{70},g^{30}	e
Pgam	b^{98},a^{2}	b	b	b
Pgm	c^{98},b^{2}	c	c	c
Tpi-2	b^{98},c^{2}	b	b	b

Table 2.9. Summary of the electrophoretic methods employed for additional allozyme markers. [1]The buffer codes refer to those used by Richardson *et al.* (1986). [2]Stain recipes are also as in Richardson *et al.* (1986).

Enzyme Abbrev.	Common name	E.C. No.	Marker	Buffer[1]	Run Time (mins)	Stain[2]
ADH	Alcohol dehydrogenase	1.1.1.1	*Adh*	C	135	
AK	Adenylate kinase	2.7.4.3	*Ak*	C	140	
ALD	fructose-bisphosphate aldolase	4.1.2.13	*Ald*	B	150	method A
GP	non-enzymatic general proteins	-	*Gp*	D	150	
PK	pyruvate kinase	2.7.1.40	*Pk-1,Pk-2*	C	110	

Table 2.10. Allozyme profiles of adults and third instar larvae at the 34 loci found to be variable in the study on the molecular identification of larvae. Individuals are listed numerically by taxon (VI = *C. vicina*, other codes as in Table 2.1) and life history stage (L = larva, other individuals are adults), e.g. ST-1 and ST-L1 are an adult and larva of *C. stygia*, respectively. Codes for loci: 1 = *Acon-1*, 2 = *Acon-2*, 3 = *Acon-3*, 4 = *Acp*, 5 = *Acyc*, 6 = *Adh*, 7 = *Ald*, 8 = *Dia*, 9 = *Enol*, 10 = *Est-1*, 11 = *Est-2*, 12 = *Gda*, 13 = *Gldh*, 14 = *Got-1*, 15 = *Got-2*, 16 = *Gp*, 17 = *Gpi*,18 = *Hex*, 19 = *Hk-1*, 20 = *Hk-2*, 21 = *Idh*, 22 = *Mdh-2*, 23 = *Me-1*, 24 = *Me-2*, 25 = *Mpi*, 26 = *Ndpk*, 27 = *PepA*, 28 = *PepB*, 29 = *PepD-1*, 30 = *PepD-2*, 31 = *PepS*, 32 = *Pgm*, 33 = *Sordh*, 34 = *Tpi-2*. A hyphen indicates that the locus could not be scored in this individual.

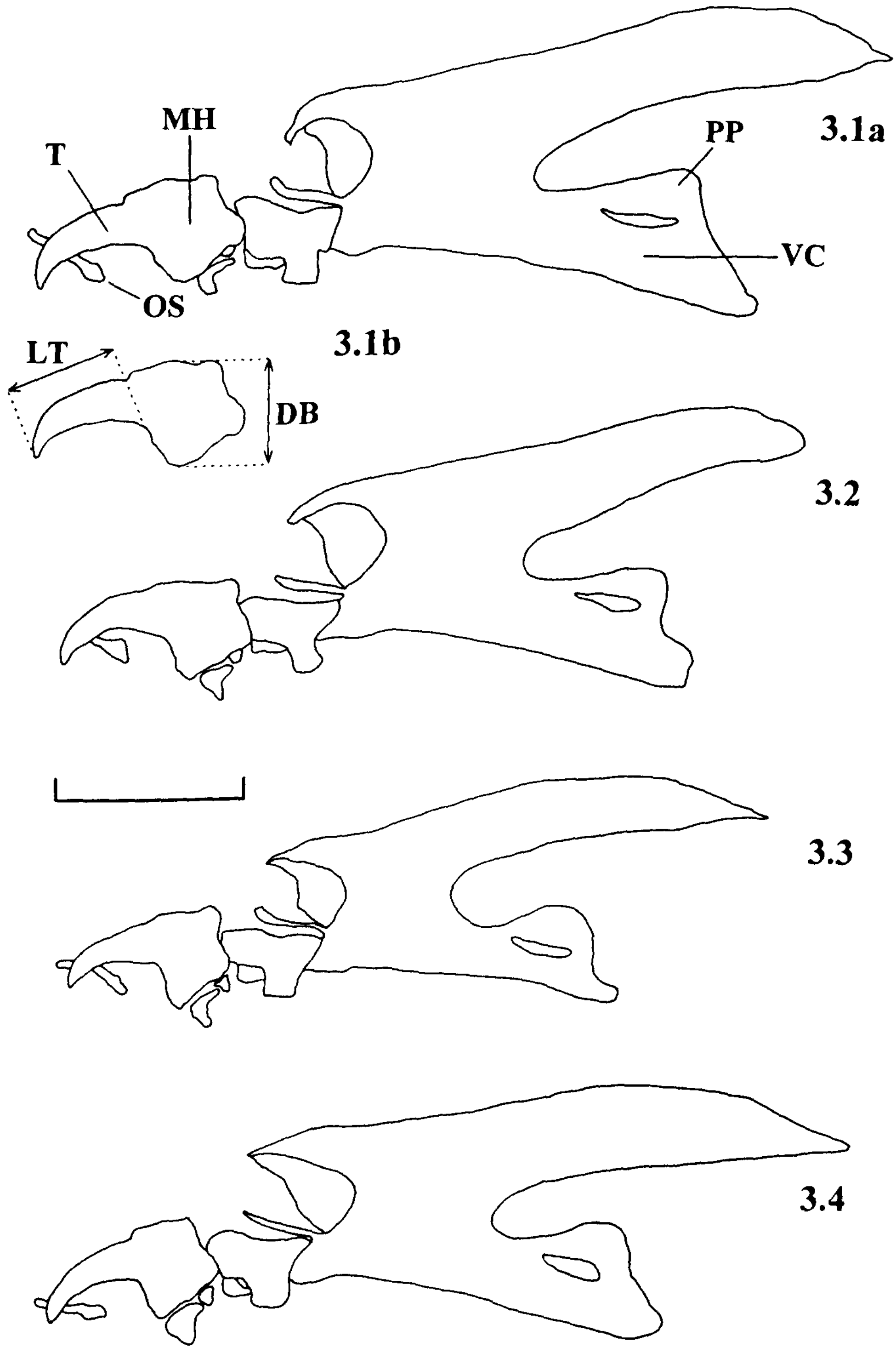
Individual	Locus																																
	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18	19	20	21	22	23	24	25	26	27	28	29	30	31	32	33	34
ST-1	b	b	b	c	df	c	a	e	a	a	a	be	c	a	a	-	a	d	d	a	a	a	a	b	a	a	b	e	c	-	a	ab	c	a
ST-2	bd	b	ab	c	fg	c	a	e	a	a	a	be	-	a	a	-	a	d	d	-	a	a	a	b	ab	a	b	e	c	-	a	a	c	a
ST-L1	b	b	b	-	f	c	a	e	a	a	a	e	-	a	a	-	a	d	d	-	a	a	a	b	ab	a	b	e	c	-	a	ab	c	a
DU-1	a	c	d	a	e	ad	b	c	d	cd	c	cf	b	b	a	-	b	c	ab	a	b	b	c	c	ce	b	c	bc	d	a	d	d	ab	b
DU-L1	a	c	d	a	e	a	b	c	d	cd	c	af	-	b	a	a	b	c	ab	-	b	b	c	bc	eg	b	c	b	d	a	d	d	ab	b
DU-L2	a	c	d	a	e	a	b	c	d	cd	c	af	-	b	ac	a	b	c	ab	-	b	b	c	bc	cg	b	c	b	d	a	d	d	b	b
DU-L3	a	c	d	a	e	ad	b	c	d	cd	c	cf	-	b	ac	ab	b	c	b	-	b	b	c	c	ci	b	c	bc	d	a	d	d	b	b
DU-L4	a	c	d	a	e	a	b	c	d	cd	c	c	-	b	ac	ab	b	c	ab	-	b	b	c	c	ei	b	c	b	d	a	d	d	b	b
DU-L5	a	c	d	a	e	a	b	c	d	cd	c	cf	-	b	ac	a	b	c	b	-	b	b	c	bc	eg	b	c	b	d	a	d	d	b	b
HI-1	a	b	d	a	c	d	b	cd	b	cd	c	dh	a	b	a	-	b	b	c	a	b	ab	b	a	d	b	a	bc	ab	b	b	c	b	b
HI-2	a	b	d	a	c	d	b	cd	b	cd	c	dg	a	b	b	-	b	b	c	a	b	a	b	a	d	b	a	ac	ab	b	bc	c	b	b
HI-3	a	b	d	-	ce	d	b	c	b	c	c	dh	a	b	ab	-	b	b	c	a	b	ab	bd	a	d	b	a	c	ab	b	b	c	b	b
HI-L1	a	b	d	-	ac	d	b	c	b	c	c	dh	-	b	a	a	b	b	c	-	b	a	b	a	d	b	a	bc	ab	b	b	c	b	b
HI-L2	a	b	d	a	c	d	b	c	b	c	c	h	-	b	a	a	b	b	c	-	b	a	b	a	d	b	a	bc	b	b	b	c	b	b
HI-L3	a	b	d	a	ce	d	b	cd	b	cd	c	gh	-	b	a	a	b	b	c	-	b	ab	b	a	d	b	a	c	a	b	b	c	b	b
HI-L4	a	b	d	a	c	d	b	cd	b	bd	c	dh	-	b	a	a	b	b	c	-	b	ab	b	a	d	b	a	c	a	b	b	c	b	b
HI-L5	a	b	d	-	ce	d	b	c	b	cd	c	gh	-	b	-	a	b	b	c	-	b	a	b	a	d	b	a	c	a	b	b	c	b	b
VI-1	c	a	a	b	b	b	b	ab	c	c	b	ad	-	b	a	-	b	a	e	b	b	b	e	b	fh	b	b	d	d	c	e	de	c	b
VI-L1	c	a	ac	-	b	b	b	b	c	c	b	ad	-	b	a	a	b	a	de	-	b	b	e	b	f	b	b	d	d	c	e	de	c	b
VI-L2	c	a	ac	b	b	b	b	b	c	c	b	d	-	b	a	a	b	a	de	-	b	b	e	b	f	b	b	d	d	c	e	de	c	b
VI-L3	c	a	ac	b	b	b	b	a	c	c	b	dg	-	b	a	a	b	a	e	-	b	b	e	b	f	b	b	d	d	c	e	e	c	b
VI-L4	c	a	ac	b	b	b	b	ab	c	c	b	d	-	b	a	a	b	a	de	-	b	b	e	b	f	b	b	d	d	c	e	de	c	b
VI-L5	c	a	ac	b	b	b	b	ab	c	c	b	d	-	b	a	a	b	a	e	-	b	b	e	b	f	b	b	d	d	c	e	e	c	b

Table 2.11. Summary of the expression of allozyme loci in the adults and third instar larvae of the *Calliphora* examined.

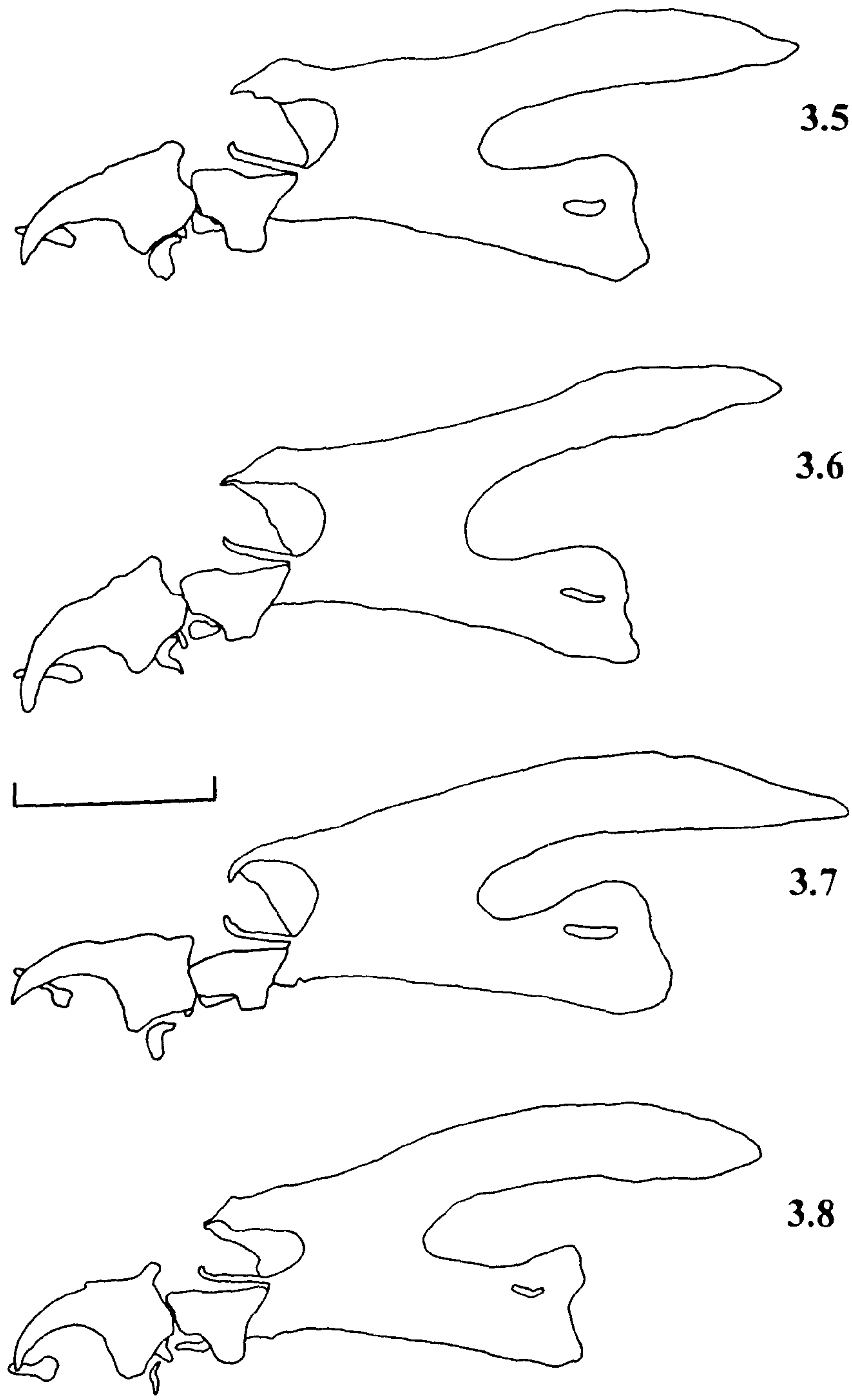
Not expressed in adults	Not expressed in larvae	Expressed and scorable in both adults and larvae
Gp	*Gldh, Hk-2*	*Acon-1, Acon-2, Acon-3, Acp, Acyc, Adh, Ak, Ald, Argk, Dia, Enol, Est-1, Est-2, Fum, Gda, Got-1, Got-2, Gpi, Hex, Hk-1, Idh, Mdh-1, Mdh-2, Me-1, Me-2, Mpi, Ndpk, PepA, PepB, PepD-1, PepD-2, PepS, Pgam, Pgm, Pk-1, Pk-2, Sordh, Tpi-1, Tpi-2*

Chapter 3

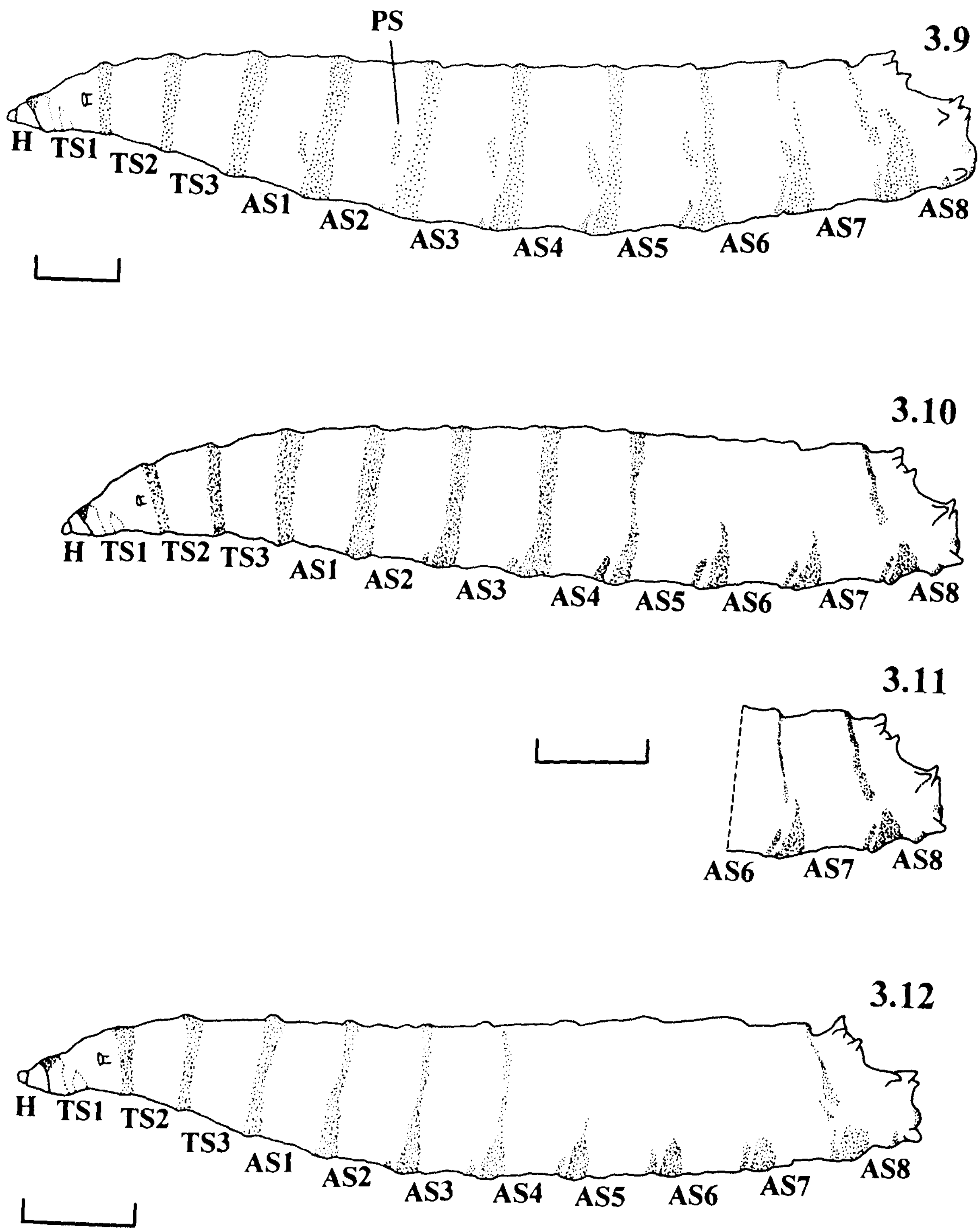
Morphological Taxonomy and Identification of Third Instar Larvae and Identification of Adults of *Calliphora* Species



Figs 3.1-3.4. Cephalopharyngeal skeletons of third instar larvae: 3.1a, *C. stygia*; 3.1b, dimensions of mouth-hook (*C. stygia*); 3.2, *C. albifrontalis*; 3.3, *C. dubia*; 3.4, *C. augur*. DB = depth of base, MH = mouth-hook, LT = length of tooth, OS = oral sclerite, PP = posterodorsal process, T = tooth, VC = ventral cornu. Scale = 0.5 mm.

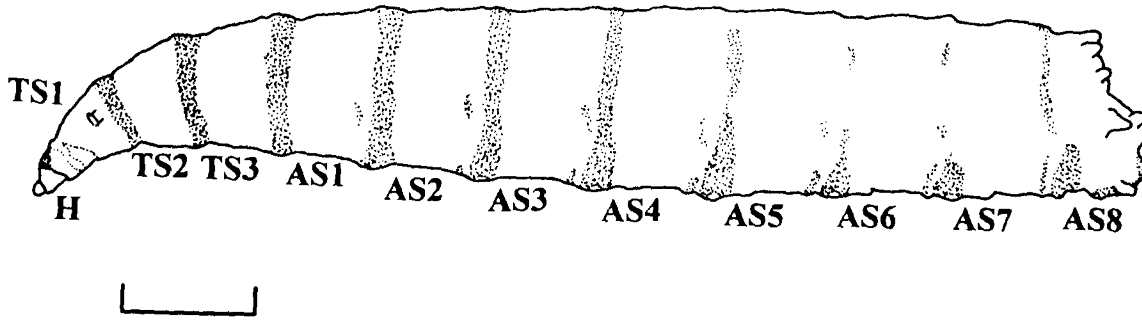


Figs 3.5-3.8. Cephalopharyngeal skeletons of third instar larvae: 3.5, *C. hilli hilli*; 3.6, *C.* sp. nov.; 3.7, *C. maritima*; 3.8, *C. vicina*. Scale = 0.5 mm.

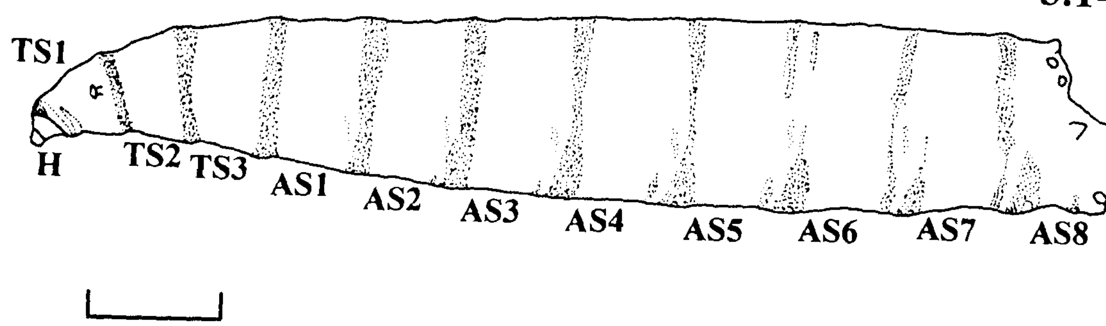


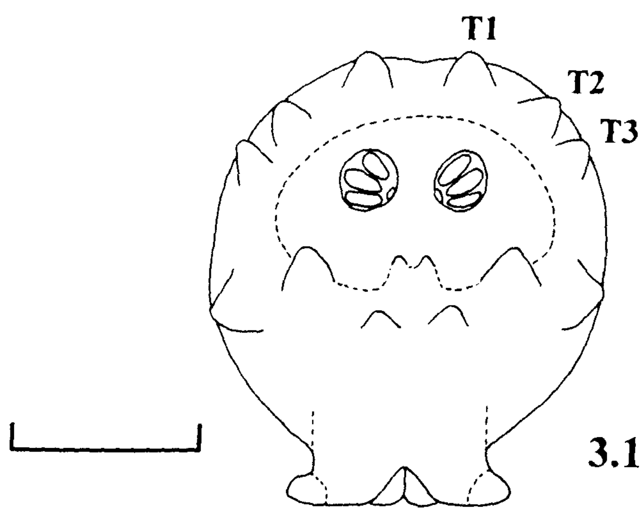
Figs 3.9-3.12. Lateral views of third instar larvae showing distribution of spinal bands: 3.9, *C. stygia*/*C. albifrontalis*; 3.10, *C. dubia*; 3.11, AS6-AS8 of *C. augur*; 3.12, *C. hilli hilli*/ *C.* sp. nov. PS = pleural spines, H = head, TH = thoracic segment, AS = abdominal segment. Scale = 2.0 mm.

3.13



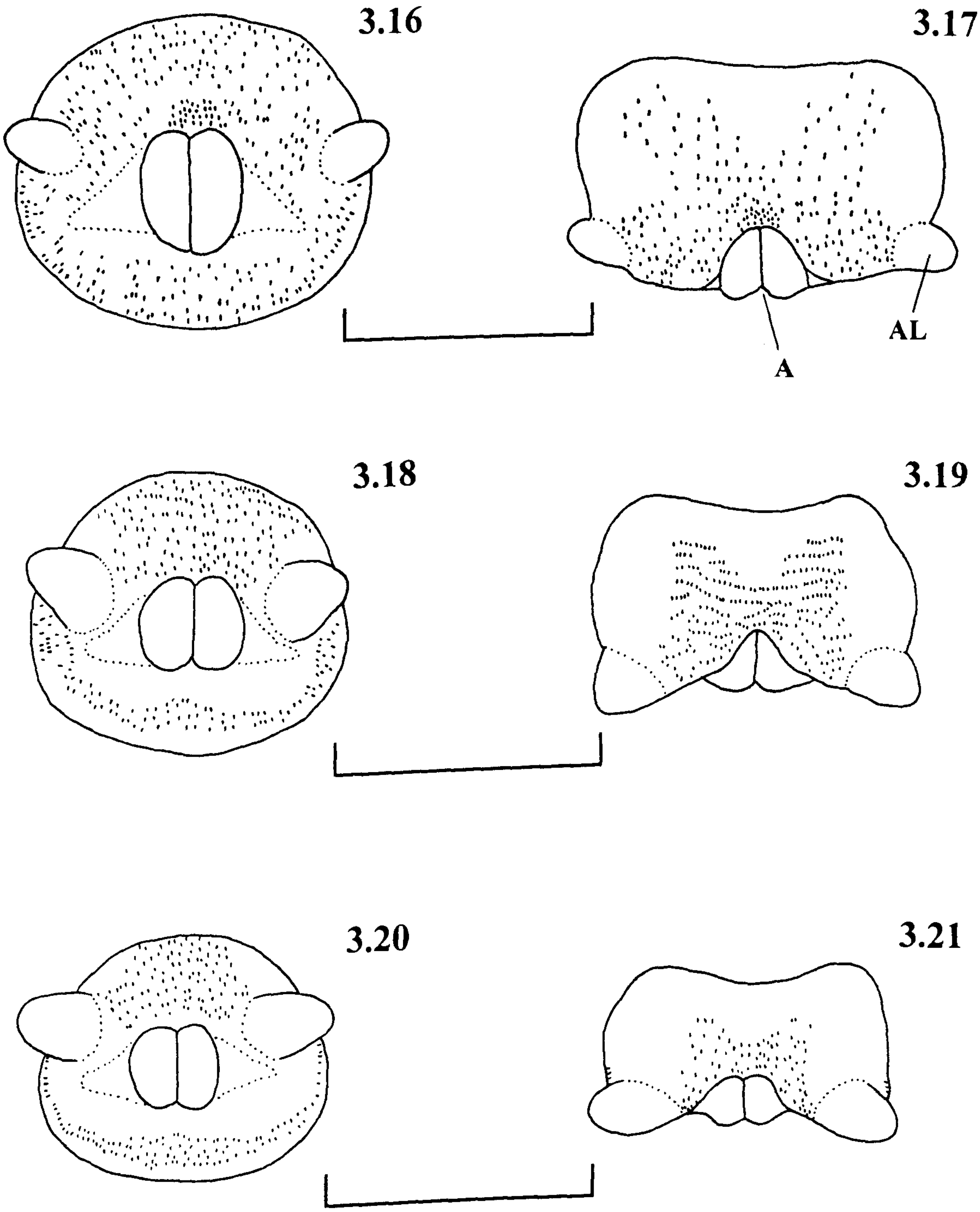
3.14



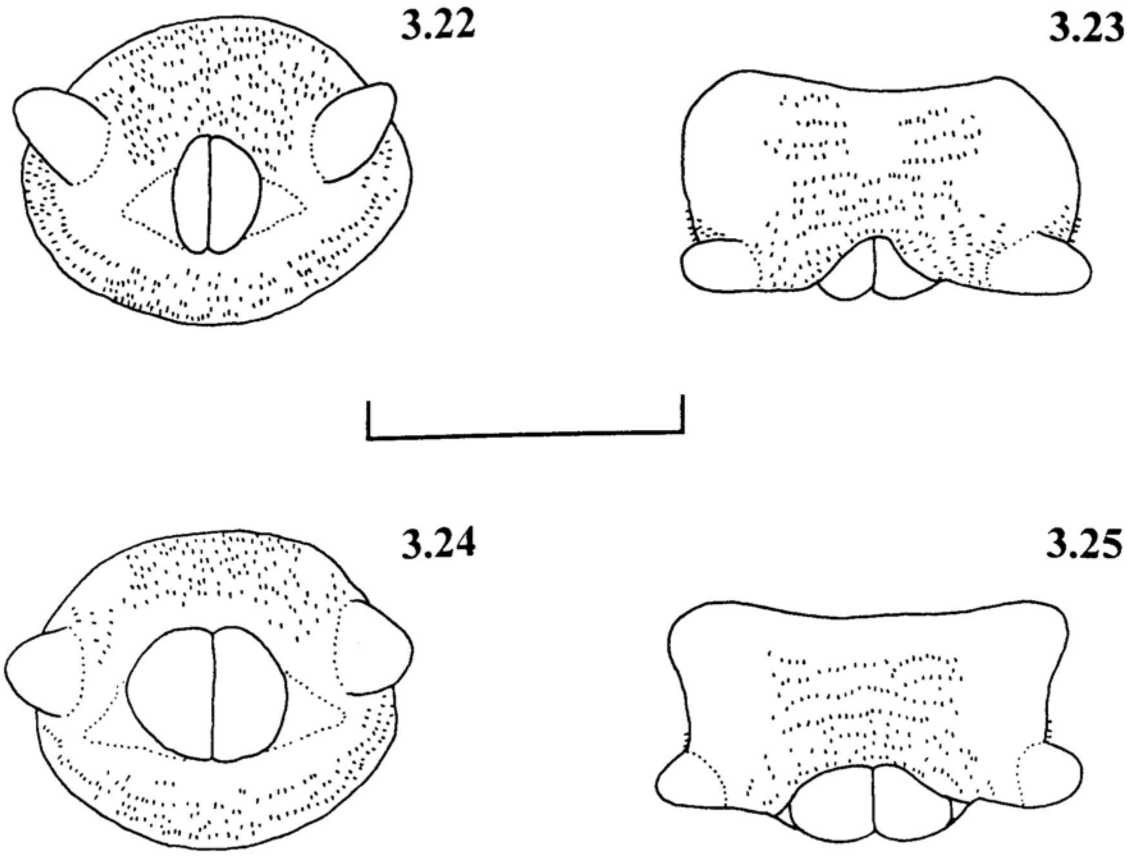


3.15

Figs 3.13-3.15. (3.13-3.14) Lateral views of third instar larvae showing distribution of spinal bands: 3.13, *C. maritima*; 3.14, *C. vicina*. Scales = 2.0 mm. (3.15) Posterior view of third instar larva of *C. stygia* showing arrangement of tubercles on AS8. T = tubercle. Scale = 2.0 mm.



Figs 3.16-3.21. Arrangement of posterior spinal band on AS8 of third instar larvae as seen in posteroventral (3.16, 3.18 and 3.20) and posterodorsal (3.17, 3.19 and 3.21) views: 3.16 and 3.17, *C. stygia*/ *C. albifrontalis*; 3.18 and 3.19, *C. augur*/ *C. dubia*; 3.20 and 3.21, *C. hilli hilli*/ *C.* sp. nov. A = anus, AL = anal lobe. Scales = 1.0 mm.



Figs 3.22-3.25. Arrangement of posterior spinal band on AS8 of third instar larvae from posteroventral (3.22 and 3.24) and posterodorsal (3.23 and 3.25) views: 3.22 and 3.23, *C. maritima*; 3.24 and 3.25, *C. vicina*. Scale = 1.0 mm.

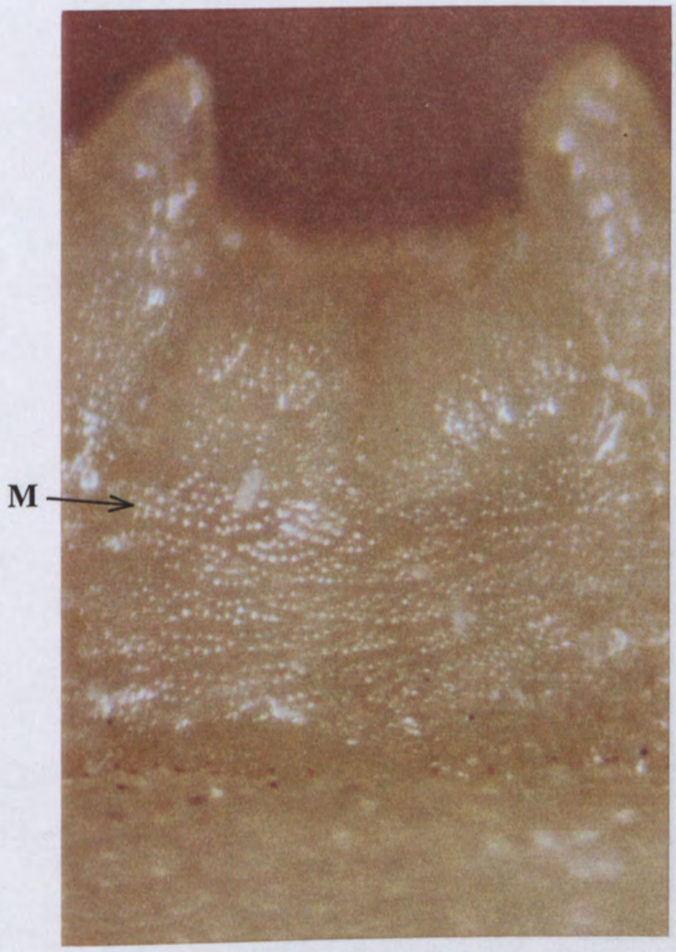
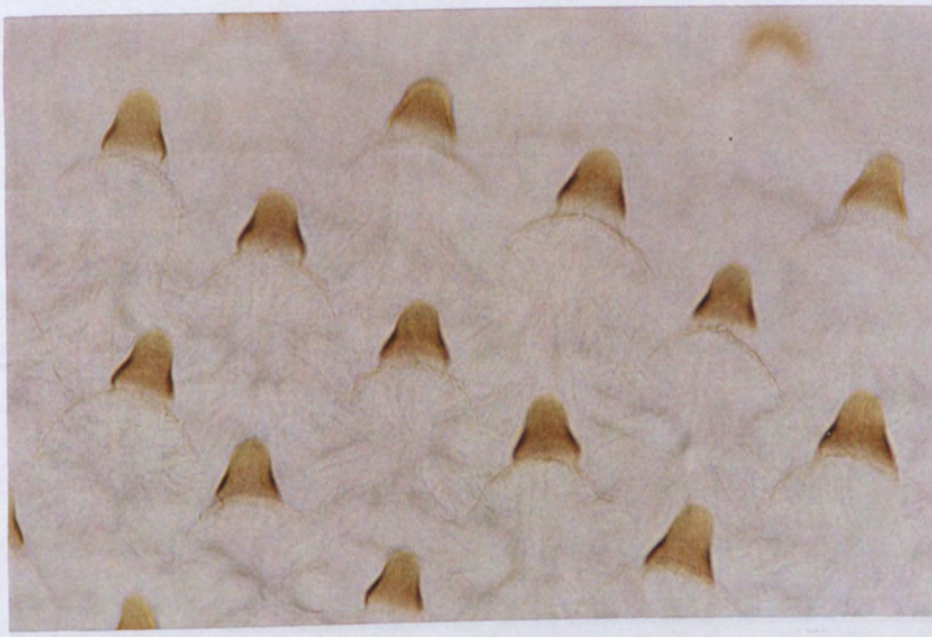


Fig. 3.26. Microtubercles on dorsal surface of AS8 of third instar larva of *C. stygia* (×100). M = microtubercles.

Fig. 3.27. Microtubercles on dorsal surface of AS8 of third instar larva of *C. dubia* (×100).

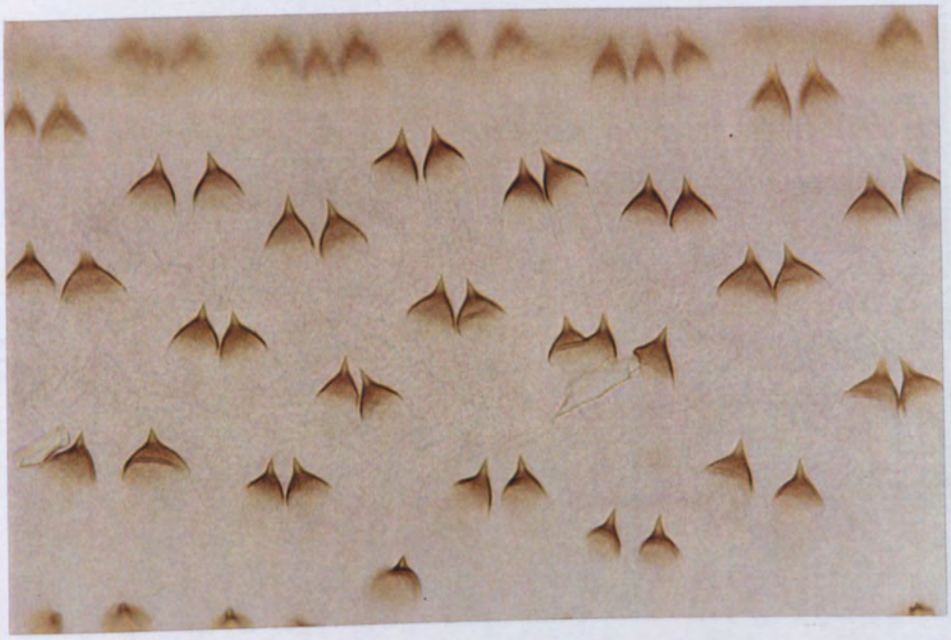
Fig. 3.28. Microtubercles on dorsal surface of AS8 of third instar larva of *C. vicina* (×100).



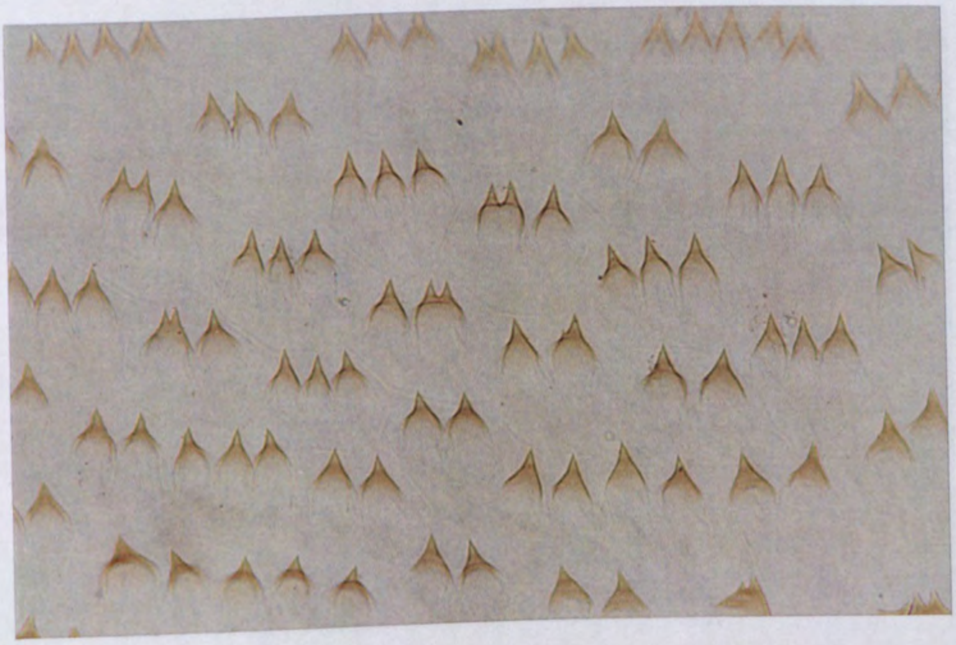
3.29

3.30

Figs 3.29 and 3.30. Spines of third instar larvae (×450): 3.29, *C. stygia*; 3.30, *C. albifrontalis*.



3.31



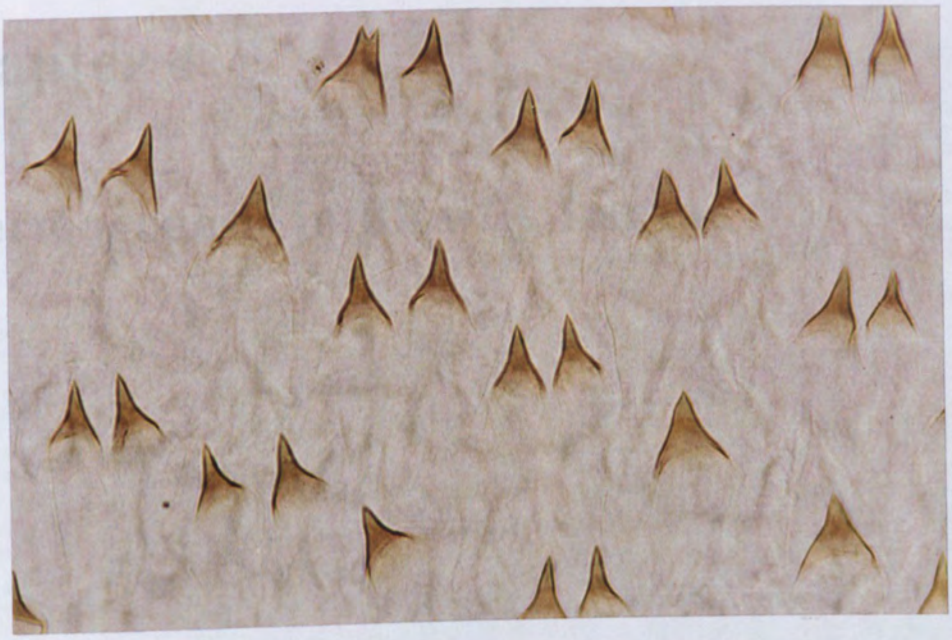
3.32

Figs 3.31 and 3.32. Spines of third instar larvae (×450): 3.31, *C. dubia*; 3.32, *C. augur*.

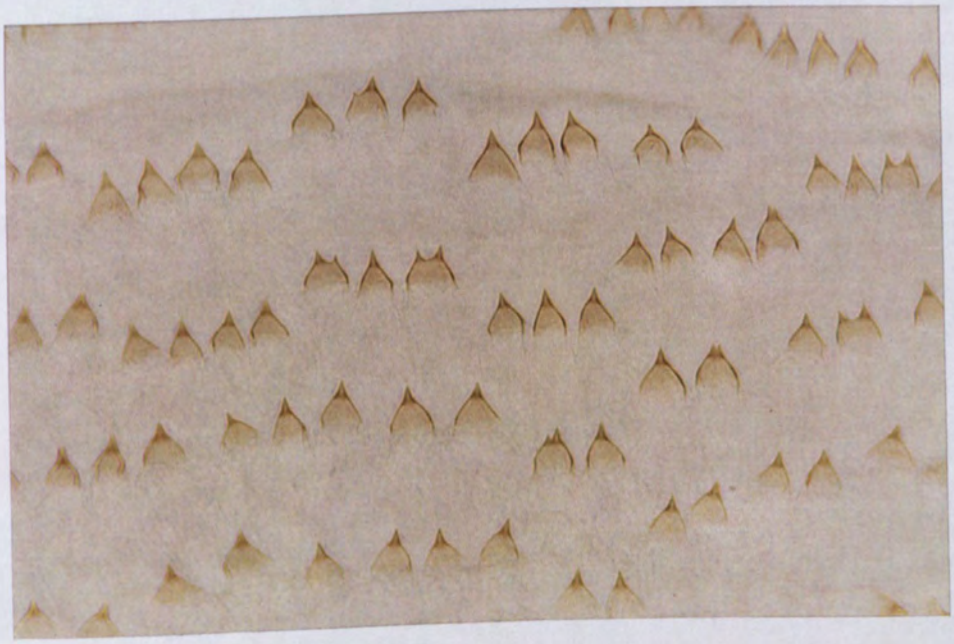
3.33

3.34

Figs 3.33 and 3.34. Spines of third instar larvae (×450): 3.33, *C. hilli hilli*; 3.34, *C.* sp. nov.



3.35



3.36

Figs 3.35 and 3.36. Spines of third instar larvae (×450): 3.35, *C. maritima*; 3.36, *C. vicina*.

Chapter 4

Thermogenesis in Blowfly Larvae

Fig. 4.1. Study site for Experiments 1, 3 and 4.

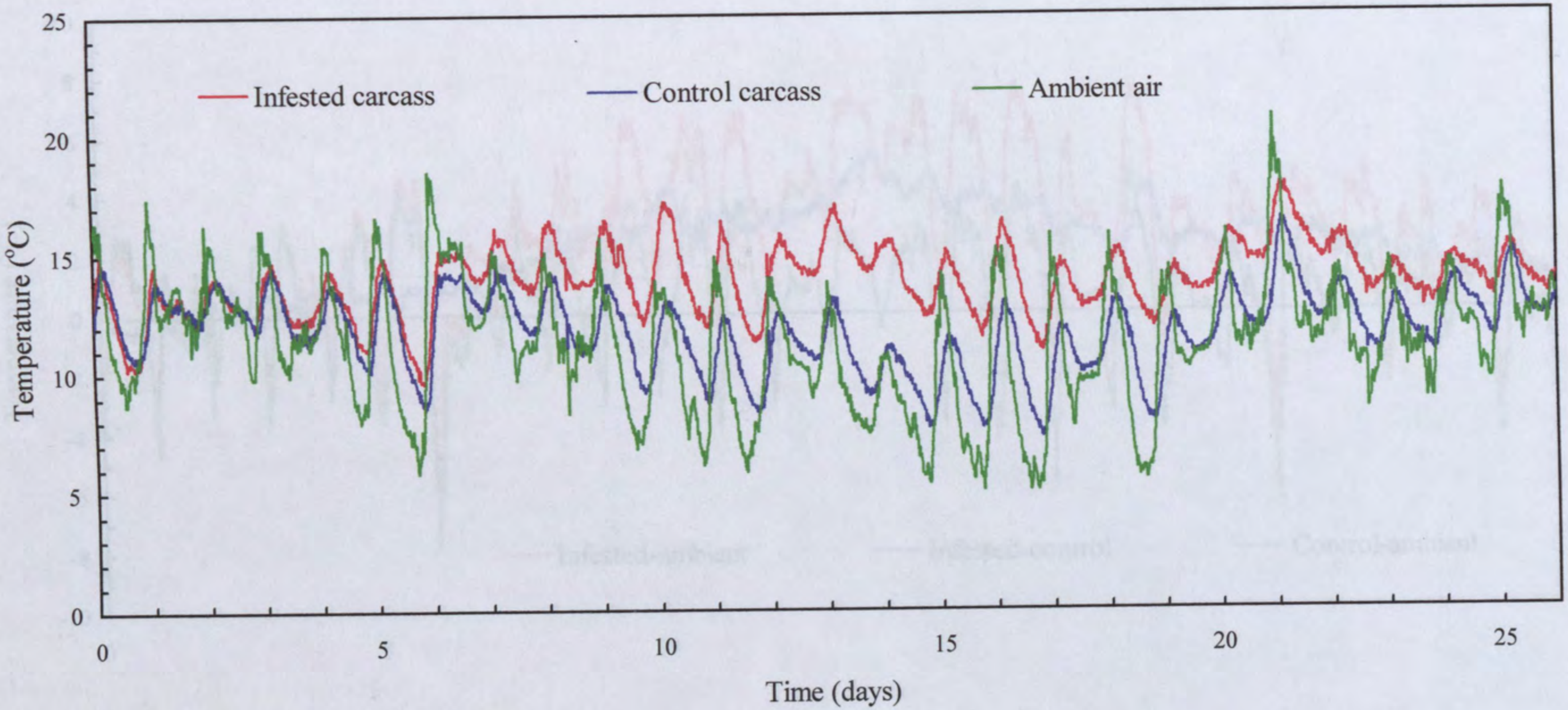


Fig. 4.2. Temperatures in a piglet carcass infested with blowfly larvae in winter, compared with simultaneous ambient air temperatures and temperatures in an uninfested piglet carcass (control).

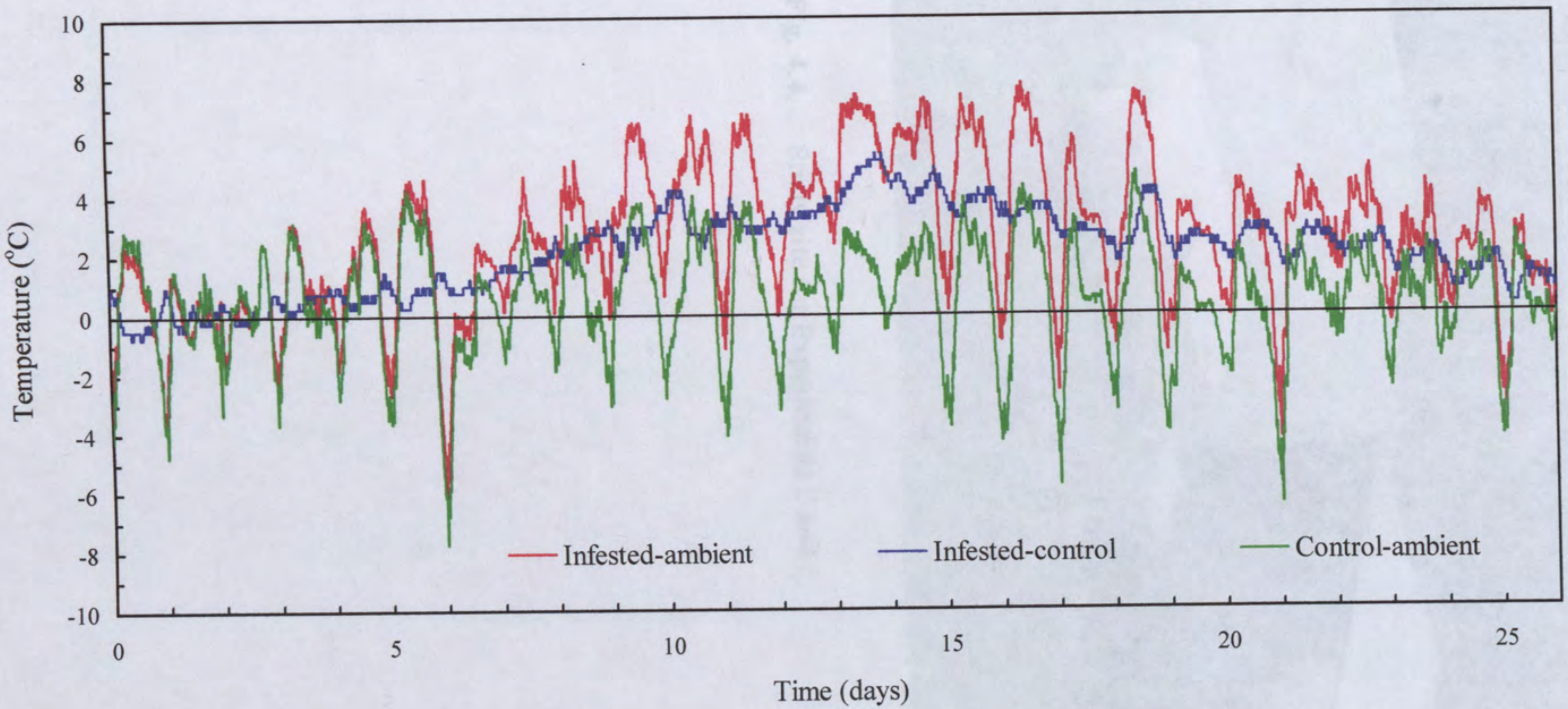


Fig. 4.3. Deviation from ambient air temperatures of temperatures in a piglet carcass infested with blowfly larvae in winter and temperatures in an adjacent uninfested piglet carcass (control), and deviation of temperatures in the infested carcass from temperatures in the control carcass.

Fig. 4.4. Study site for Experiments 2 and 5.

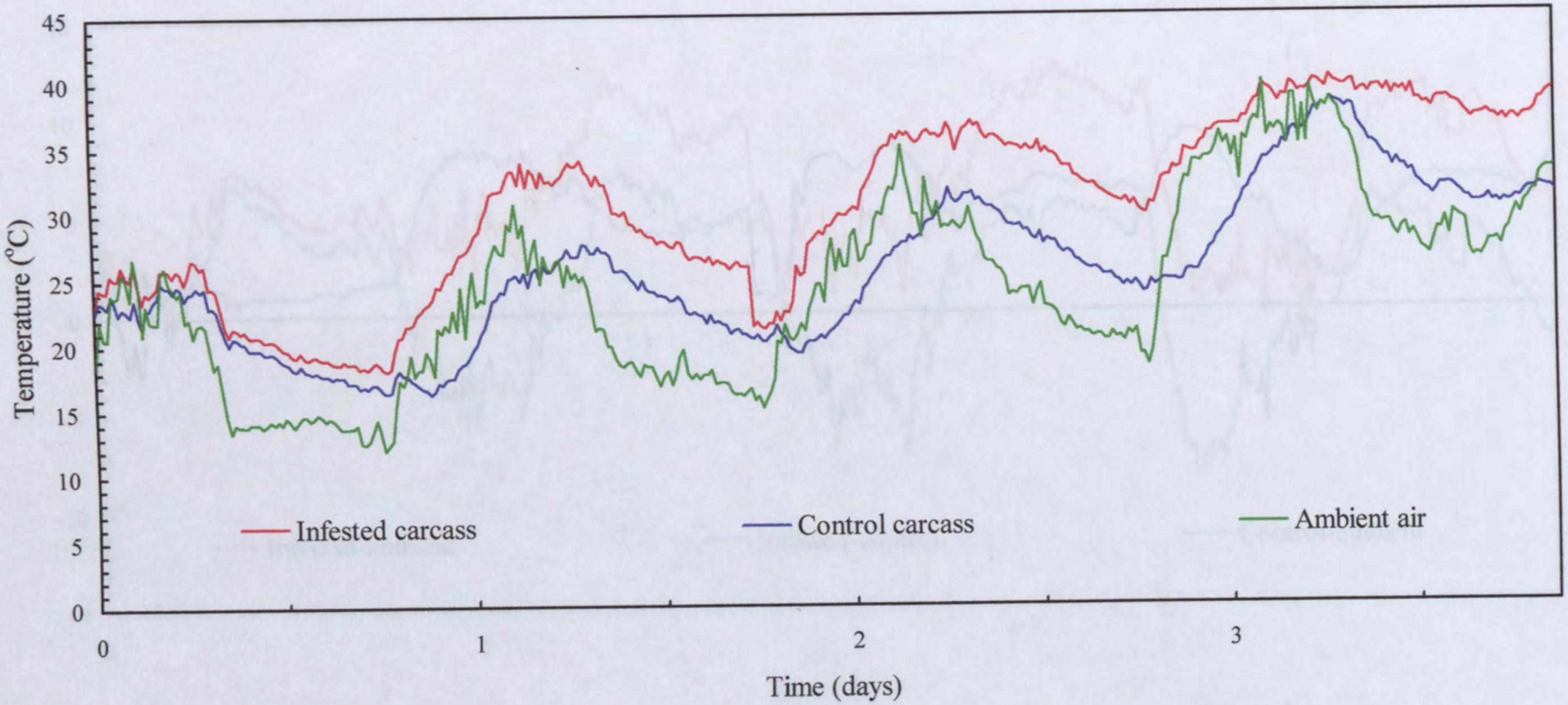


Fig. 4.5. Temperatures in a piglet carcass infested with blowfly larvae in summer, compared with simultaneous ambient air temperatures and temperatures in an uninfested piglet carcass (control).

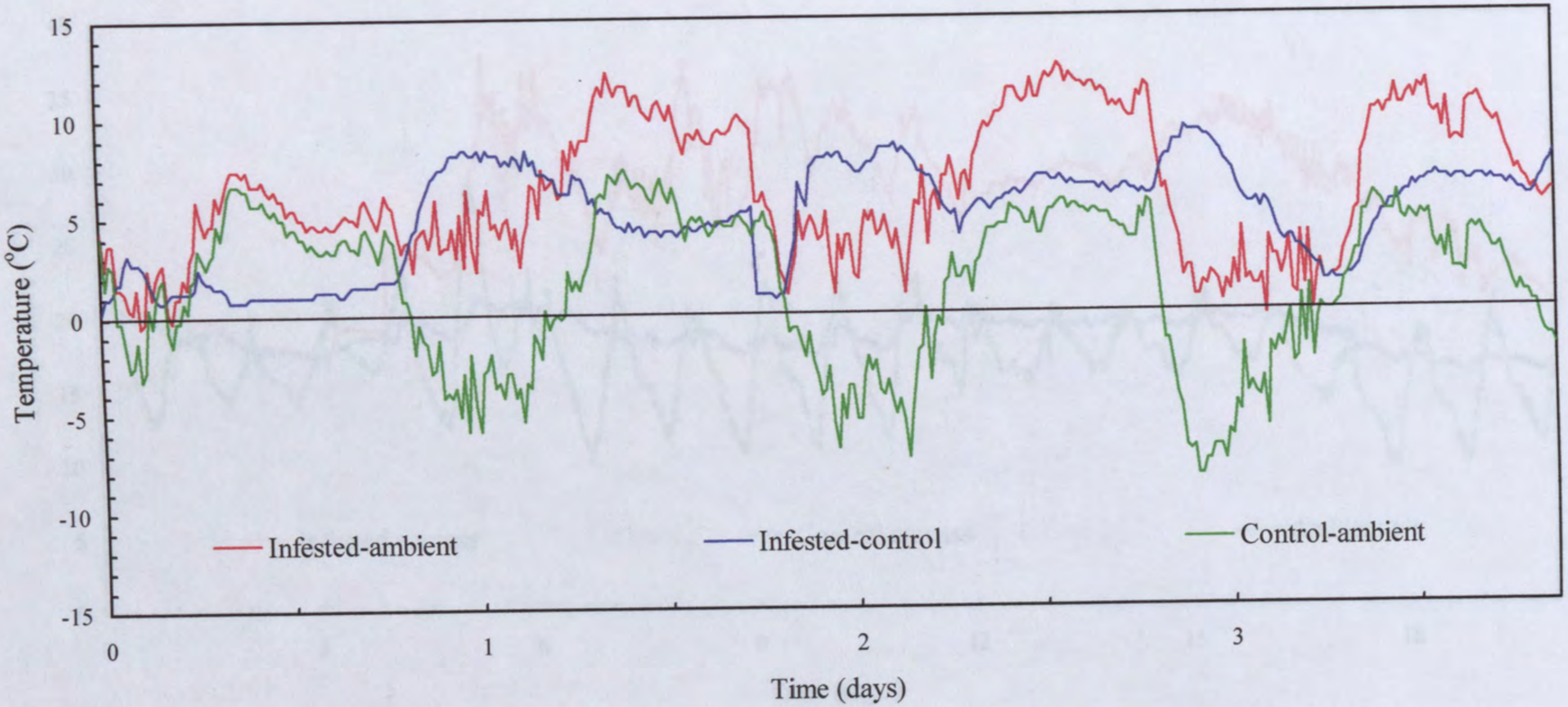


Fig. 4.6. Deviation from ambient air temperatures of temperatures in a piglet carcass infested with blowfly larvae in summer and temperatures in an adjacent uninfested piglet carcass (control), and deviation of temperatures in the infested carcass from temperatures in the control carcass.

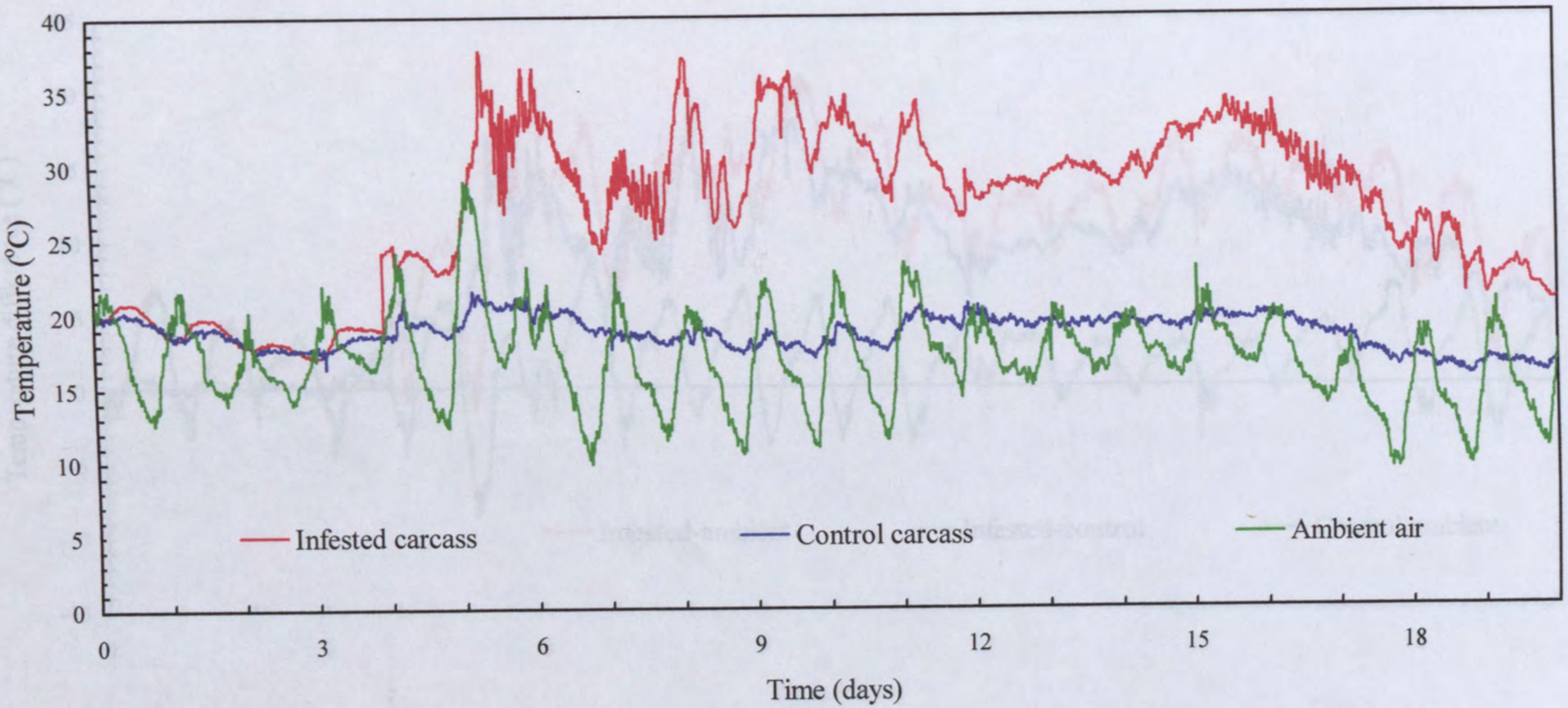


Fig. 4.7. Temperatures in a pig carcass infested with blowfly larvae in autumn, compared with simultaneous ambient air temperatures and temperatures in an uninfested pig carcass (control).

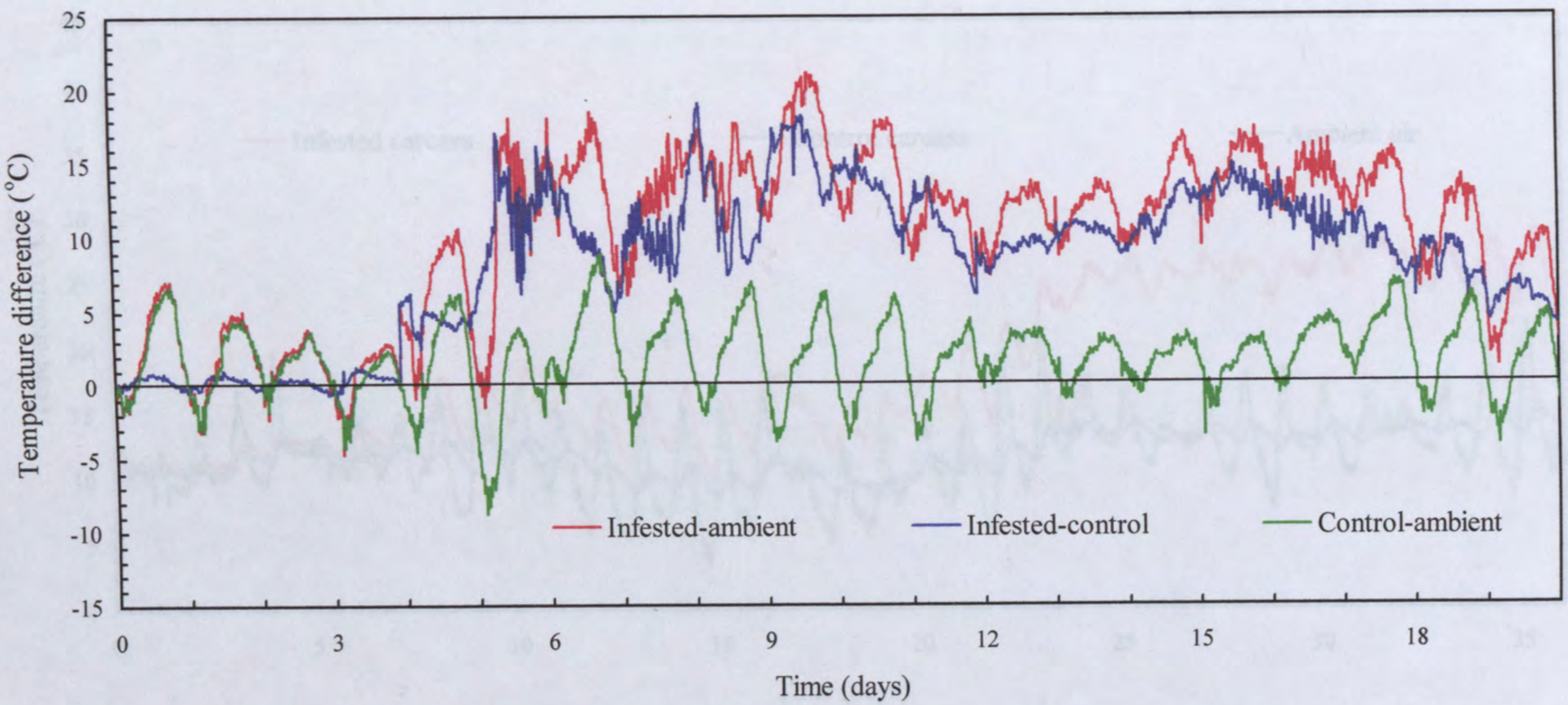


Fig. 4.8. Deviation from ambient air temperatures of temperatures in a pig carcass infested with blowfly larvae in autumn and temperatures in an adjacent uninfested pig carcass (control), and deviation of temperatures in the infested carcass from temperatures in the control carcass.

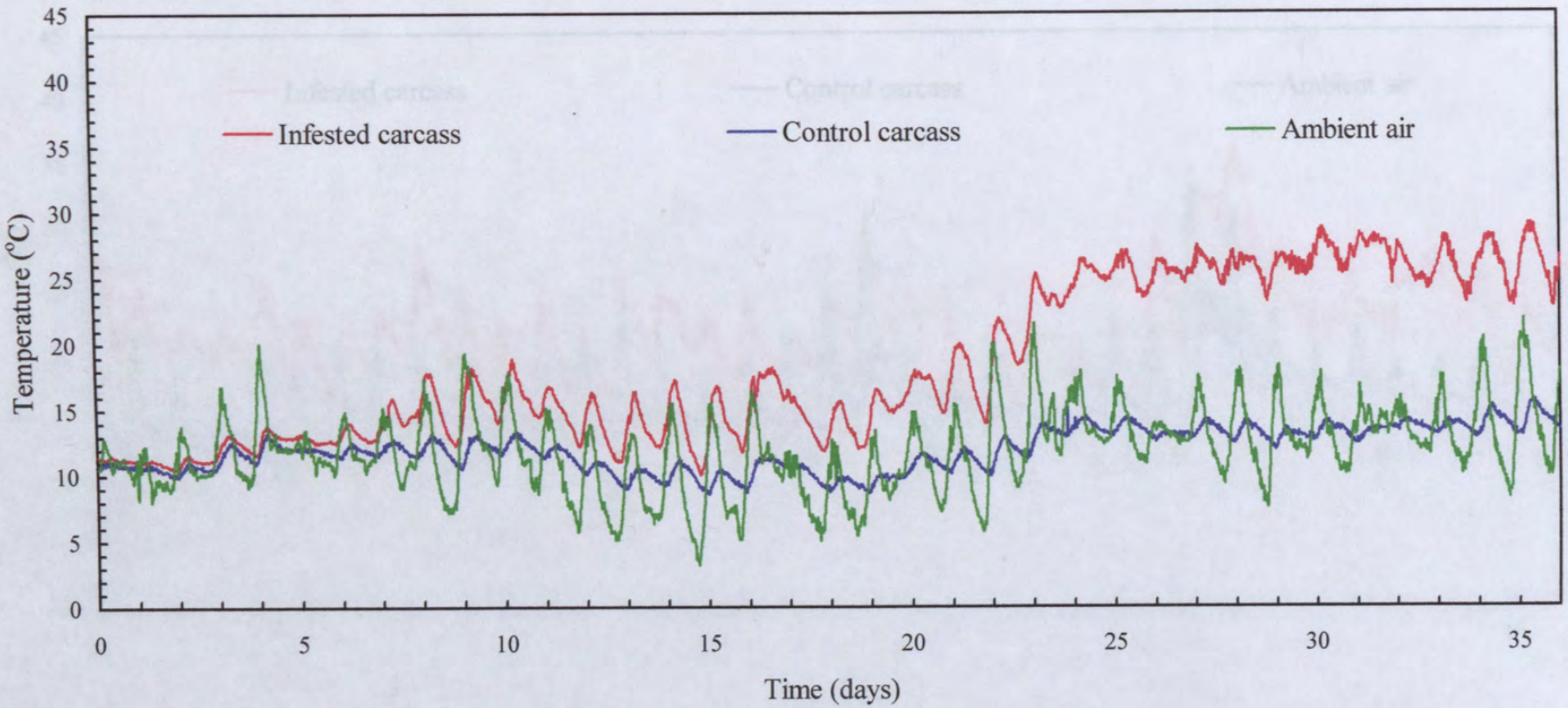


Fig. 4.9. Temperatures in a pig carcass infested with blowfly larvae in winter and spring (days 1-36, inclusive), compared with simultaneous ambient air temperatures and temperatures in an uninfested pig carcass (control).

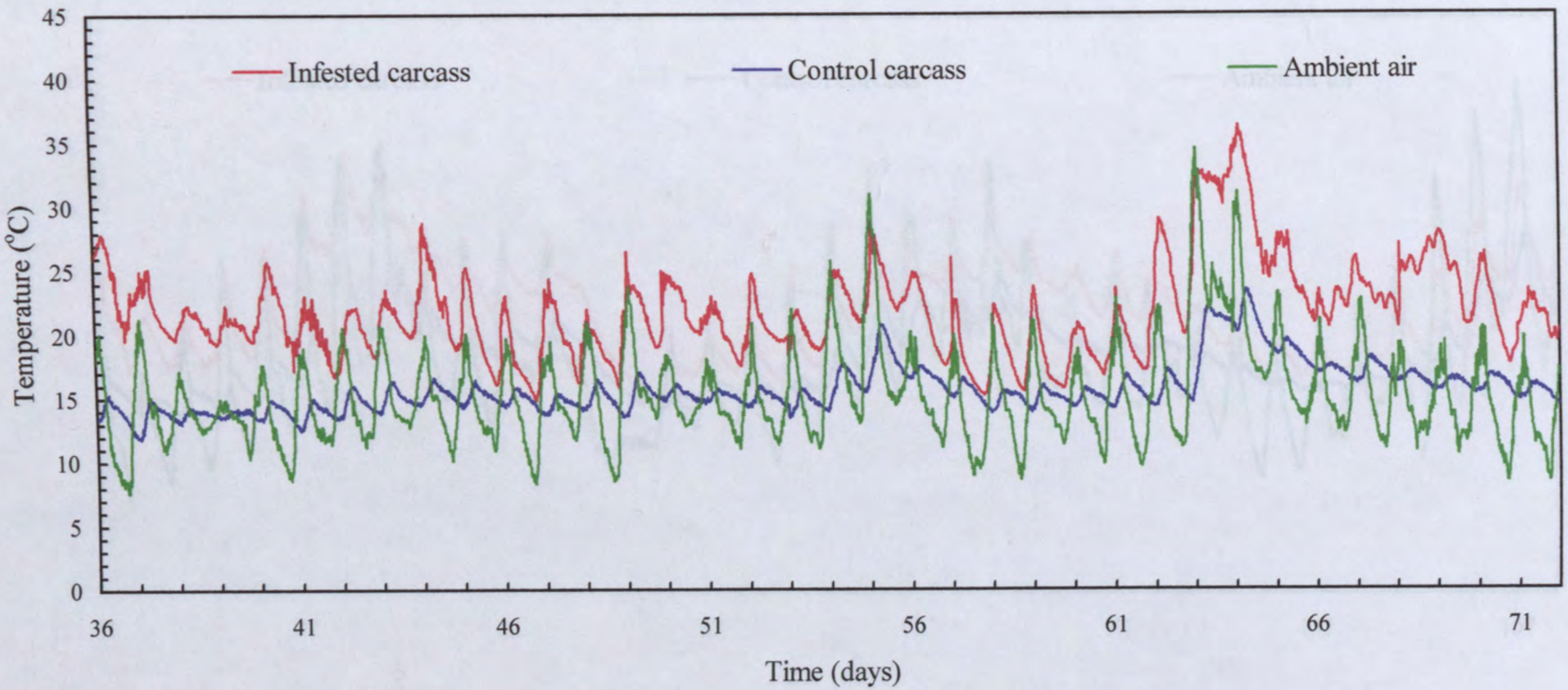


Fig. 4.10. Temperatures in a pig carcass infested with blowfly larvae in spring (days 37-72, inclusive), compared with simultaneous ambient air temperatures and temperatures in an uninfested pig carcass (control).

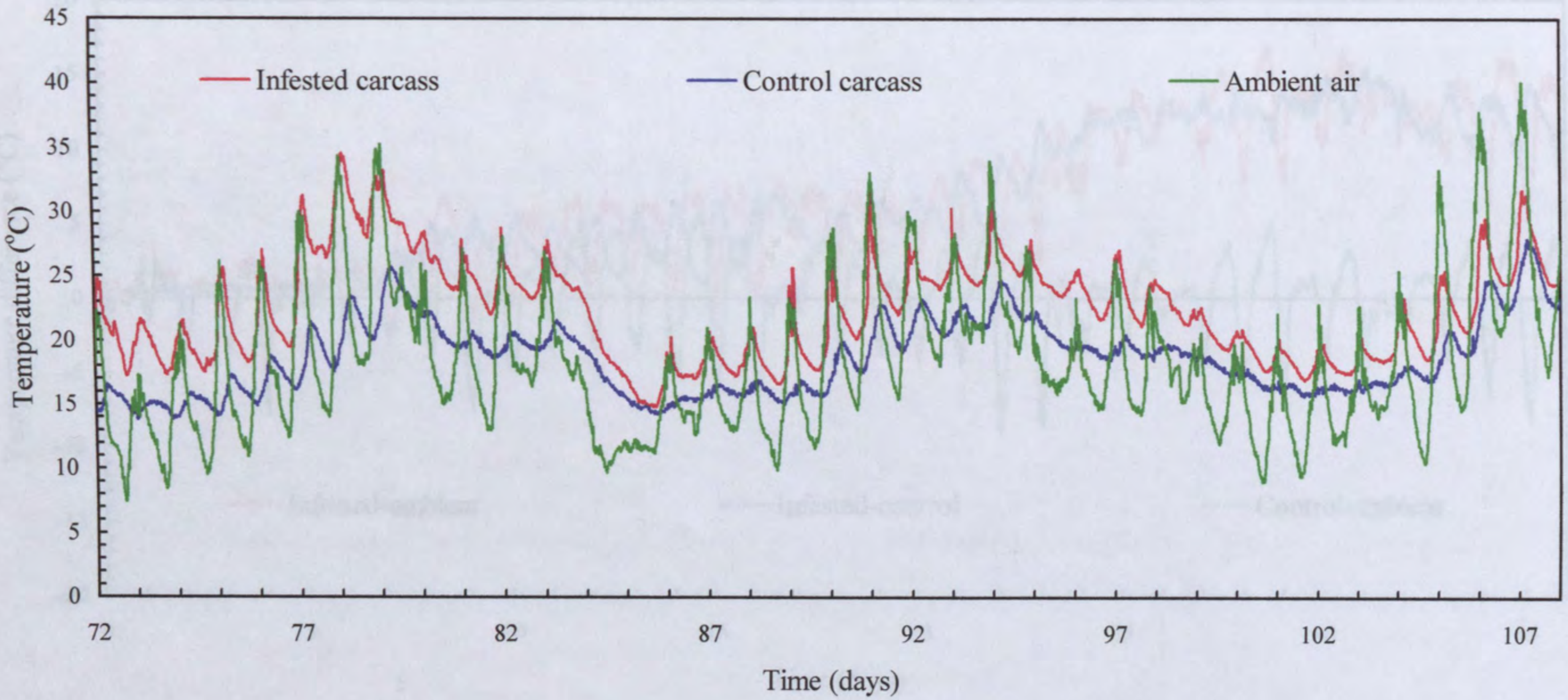


Fig. 4.11. Temperatures in a pig carcass infested with muscid larvae in spring (days 73-108, inclusive), compared with simultaneous ambient air temperatures and temperatures in an uninfested pig carcass (control).

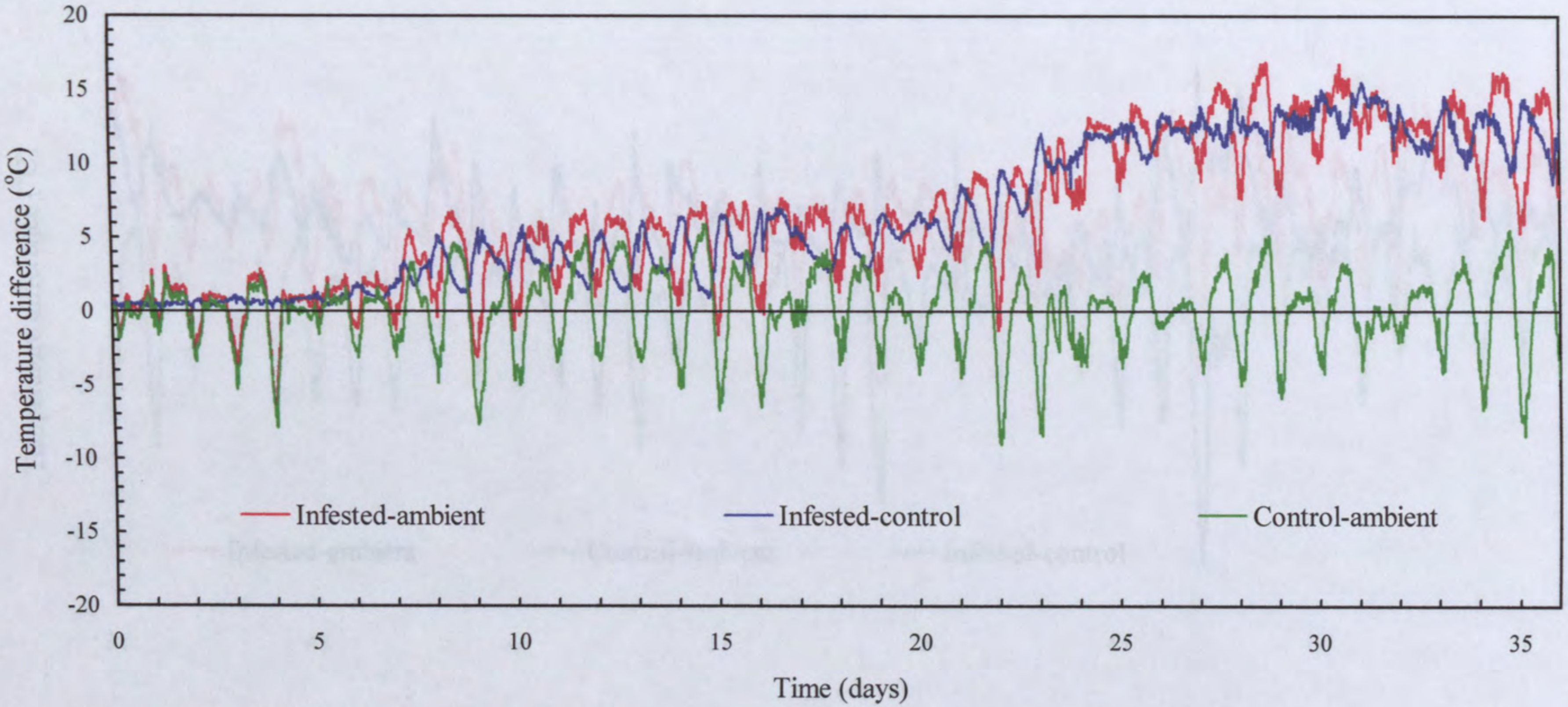


Fig. 4.12. Deviation from ambient air temperatures of temperatures in a pig carcass infested with blowfly larvae in winter and spring (days 1-36, inclusive) and temperatures in an adjacent uninfested pig carcass (control), and deviation of temperatures in the infested carcass from temperatures in the control carcass.

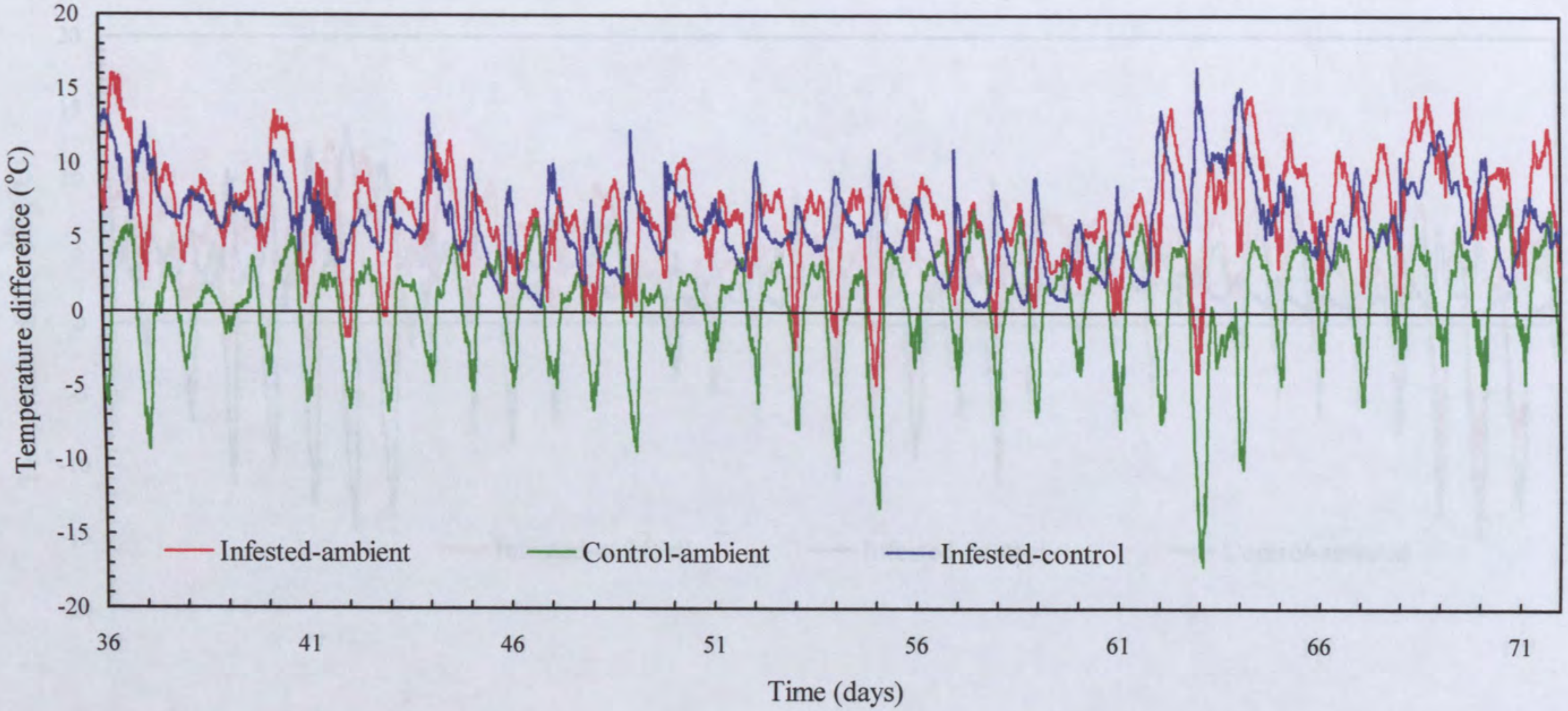


Fig. 4.13. Deviation from ambient air temperatures of temperatures in a pig carcass infested with blowfly larvae in spring (days 37-72, inclusive) and temperatures in an adjacent uninfested pig carcass (control), and deviation of temperatures in the infested carcass from temperatures in the control carcass.

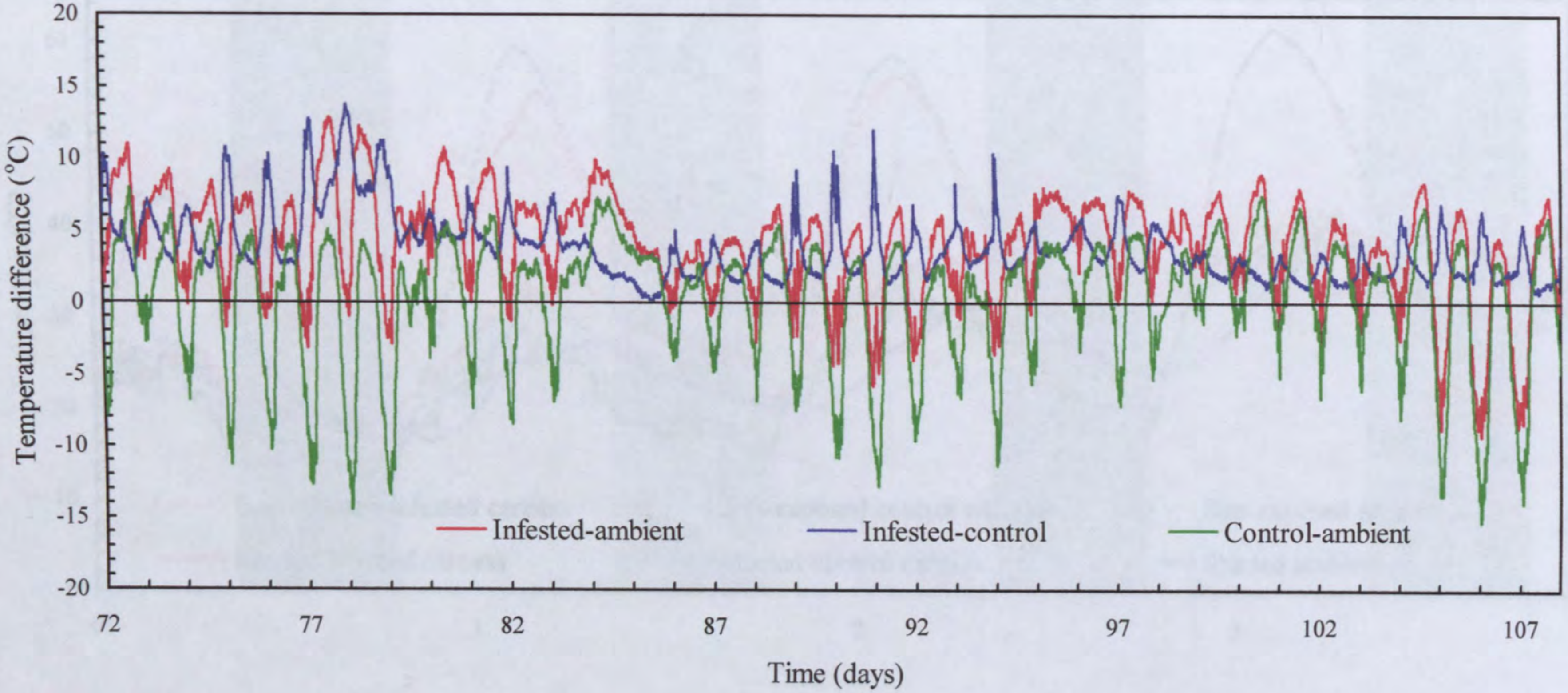


Fig. 4.14. Deviation from ambient air temperatures of temperatures in a pig carcass infested with muscid larvae in spring (days 73-108, inclusive) and temperatures in an adjacent uninfested pig carcass (control), and deviation of temperatures in the infested carcass from temperatures in the control carcass.

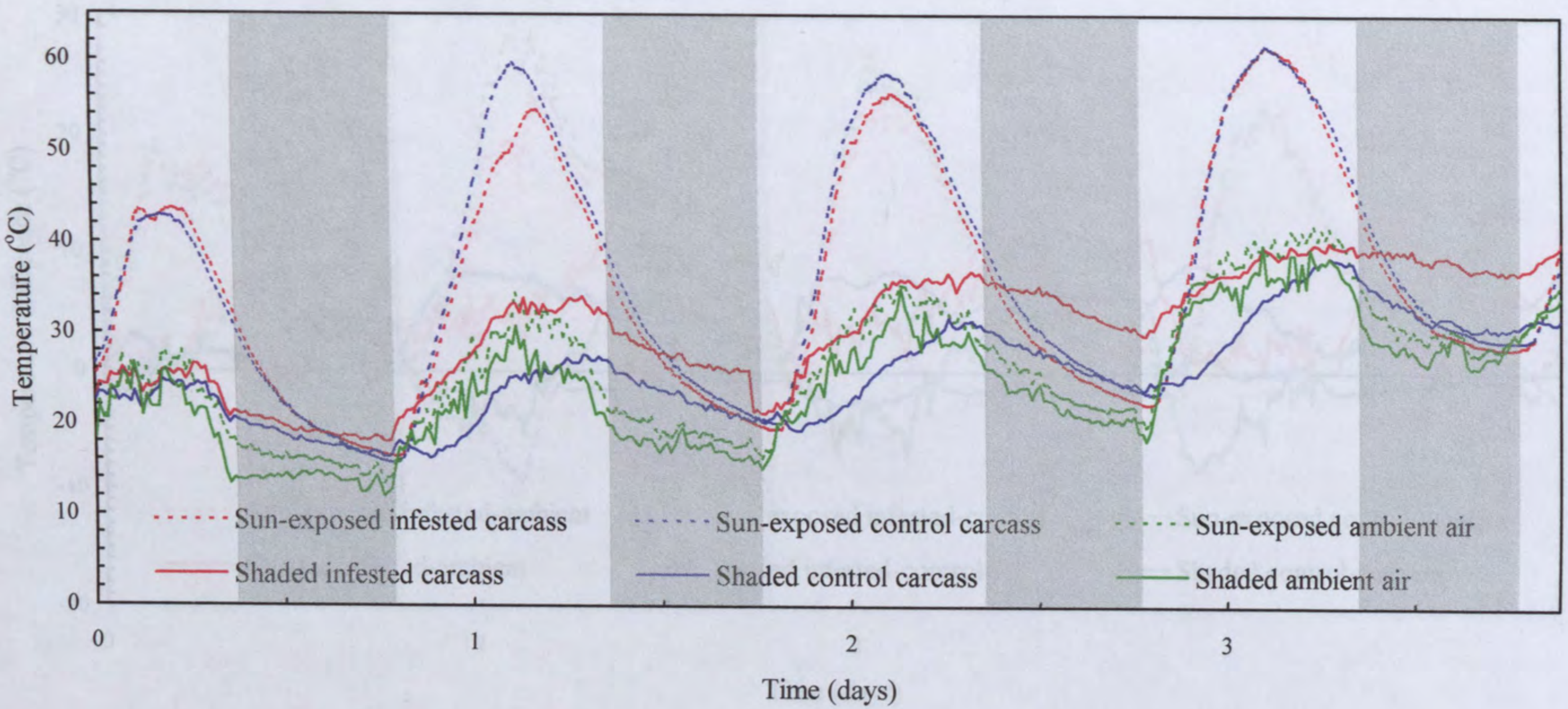


Fig. 4.15. Temperatures in a sun-exposed piglet carcass initially infested with blowfly larvae in summer, simultaneous ambient air temperatures and temperatures in an adjacent sun-exposed uninfested pig carcass (control), compared with equivalent temperatures in shaded carcasses and in the shaded ambient air. The dark bars indicate night-time.

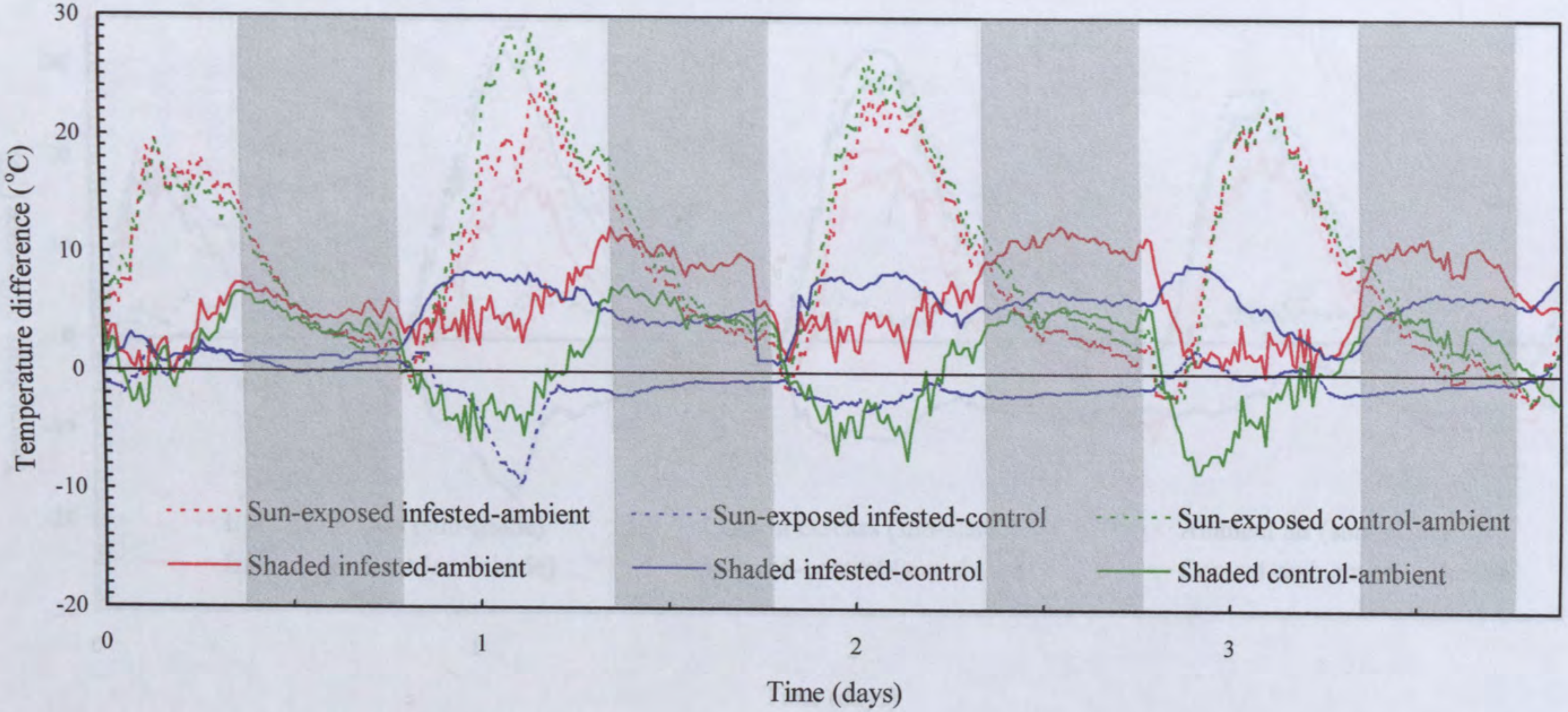


Fig. 4.16. Deviation from ambient air temperatures in the sun of temperatures in a sun-exposed piglet carcass initially infested with blowfly larvae in summer, deviation from air temperatures of temperatures in an adjacent sun-exposed uninfested piglet carcass (control), and deviation of temperatures in the infested carcass from temperatures in the control carcass, compared with equivalent temperature differences in the shade. The dark bars indicate night-time.

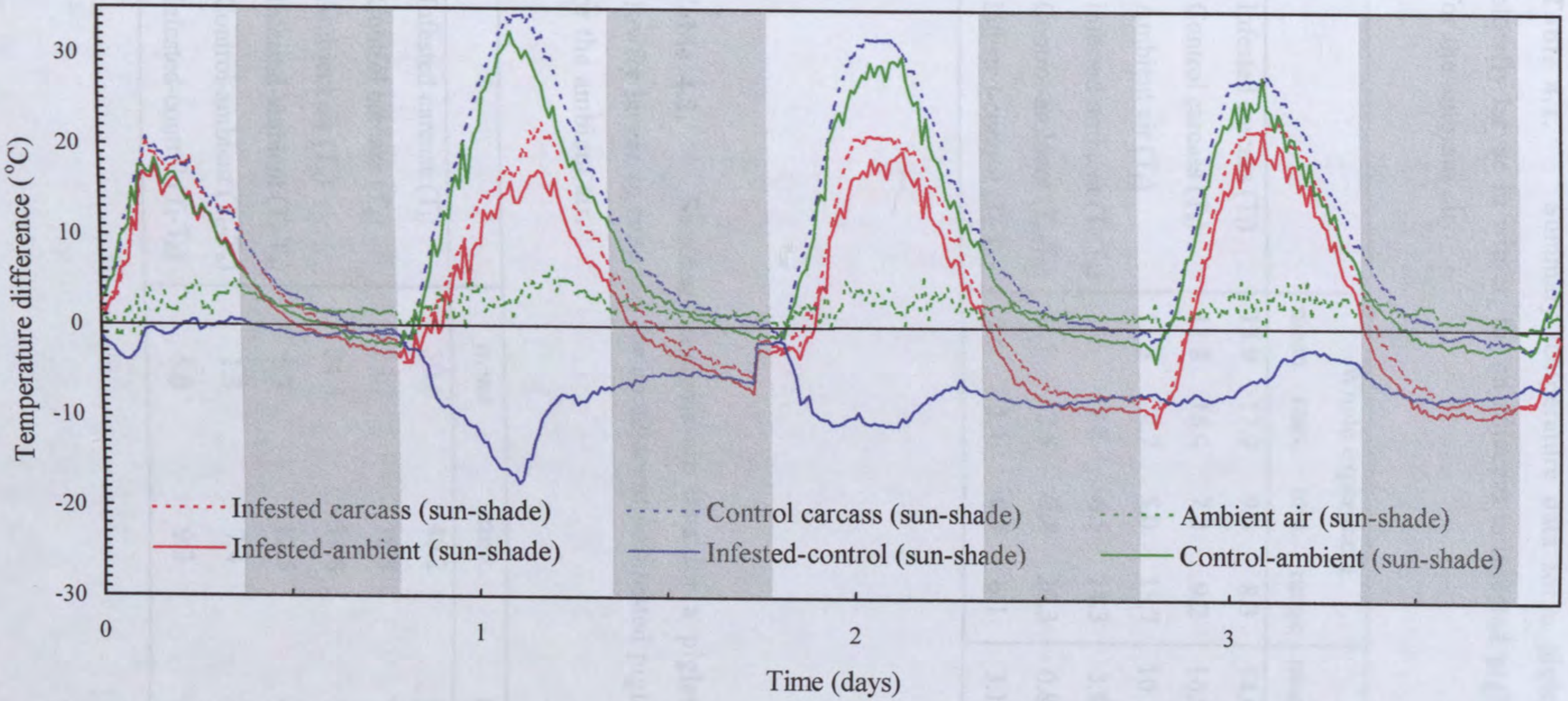


Fig. 4.17. Differences between temperatures in sun-exposed and shaded piglet carcasses initially infested and uninfested with blowfly larvae, compared with differences between ambient temperatures in the sun and shade. Also given are differences between sun-exposed and shaded carcasses in the deviation from ambient of temperatures in infested and control carcasses, and in the deviation of infested from control carcass temperatures. The dark bars indicate night-time.

Table 4.1. Summary temperature data for a piglet carcass infested with blowfly larvae in winter, for an adjacent uninfested piglet carcass (control) and for the ambient air.

	Whole experiment				Days 7-19, inclusive			
	mean	max.	min.	range	mean	max.	min.	range
Infested carcass (T_i)	13.9	17.9	9.6	8.3	14.0	17.2	10.9	6.3
Control carcass (T_c)	11.8	16.4	7.2	9.2	10.9	14.6	7.2	7.4
Ambient air (T_a)	11.3	20.7	5.0	15.7	10.1	15.8	5.0	10.8
Infested-ambient (T_i-T_a)	2.6	7.8	-6.5	14.3	3.9	7.8	-2.6	10.4
Control-ambient (T_c-T_a)	0.5	12.5	-7.8	20.3	0.8	4.8	-5.8	10.6
Infested-control (T_i-T_c)	2.1	5.4	-0.7	6.1	3.1	5.4	1.2	4.2

Table 4.2. Summary temperature data for a piglet carcass infested with blowfly larvae in summer, for an adjacent uninfested piglet carcass (control) and for the ambient air.

	mean	max.	min.	range
Infested carcass (T_i)	30.6	40.2	18.0	22.2
Control carcass (T_c)	25.7	38.5	16.2	22.3
Ambient air (T_a)	24.4	39.8	12.0	27.8
Infested-ambient (T_i-T_a)	6.3	12.5	-0.5	13.0
Control-ambient (T_c-T_a)	1.3	7.4	-8.4	15.8
Infested-control (T_i-T_c)	5.0	9.3	0.2	9.1

Table 4.3. Summary temperature data for a pig carcass infested with blowfly larvae in autumn, an adjacent uninfested pig carcass (control) and the ambient air.

	Whole experiment				Days 1-4, inclusive				Days 5-17, inclusive				Days 18-20, inclusive			
	mean	max.	min.	range	mean	max.	min.	range	mean	max.	min.	range	mean	max.	min.	range
Infested carcass (T_i)	27.0	37.8	17.1	20.7	19.0	24.2	17.1	7.1	30.1	37.8	22.7	15.1	24.5	30.2	20.6	9.6
Control carcass (T_c)	18.6	21.6	15.5	6.1	18.6	20.3	16.3	4.0	19.1	21.6	16.9	4.7	16.6	18.8	15.5	3.3
Ambient air (T_a)	16.8	29.0	9.3	19.7	17.1	22.0	12.6	9.4	17.3	29.0	9.8	19.2	14.2	20.7	9.3	11.4
Infested-ambient (T_i-T_a)	10.2	21.2	-4.7	25.9	1.8	7.1	-4.7	11.8	12.8	21.2	-1.5	22.7	10.3	16	1.2	14.8
Control-ambient (T_c-T_a)	1.8	9.0	-8.8	17.8	1.4	6.8	-4.3	11.1	1.8	9.0	-8.8	17.8	2.4	7.1	-4.2	11.3
Infested-control (T_i-T_c)	8.4	19.2	-0.8	20.0	0.4	5.8	-0.8	6.6	11.0	19.2	2.5	16.7	7.9	11.8	4.1	7.7

Table 4.4a. Summary temperature data, divided into four periods, for a pig carcass infested with blowfly larvae in winter and spring, an adjacent pig carcass (control) and the ambient air.

	Days 1-6, inclusive				Days 7-23, inclusive				Days 24-37, inclusive				Days 38-53, inclusive			
	mean	max.	min.	range	mean	max.	min.	range	mean	max.	min.	range	mean	max.	min.	range
Infested carcass (T_i)	11.9	13.8	10.4	3.4	15.2	22.5	10.0	12.5	25.6	29.0	19.6	9.4	20.7	28.8	14.8	14.0
Control carcass (T_c)	11.3	13.3	9.9	3.4	10.9	13.3	8.5	4.8	13.5	15.6	11.8	3.8	14.7	17.0	11.8	5.2
Ambient air (T_a)	11.6	20.1	8.0	12.1	10.7	20.0	3.2	16.8	13.5	21.8	7.5	14.3	14.5	23.8	8.3	15.5
Infested-ambient (T_i-T_a)	0.4	3.1	-7.3	10.4	4.5	9.9	-3.1	13.0	12.1	16.9	2.4	14.5	6.2	13.6	-1.7	15.3
Control-ambient (T_c-T_a)	-0.3	2.6	-7.9	10.5	0.3	5.9	-9.0	14.9	0	5.8	-8.5	14.3	0.2	6.3	-9.4	15.7
Infested-control (T_i-T_c)	0.6	1.7	0.1	1.5	4.3	10.4	0.8	9.6	12.2	15.6	6.2	9.4	6.0	13.4	0.3	13.1

Table 4.4b. Summary temperature data for a pig carcass infested with blowfly larvae in winter and spring, an adjacent uninfested pig carcass (control) and the ambient air.

	Days 1-53, inclusive			
	mean	max.	min.	range
Infested carcass (T_i)	19.3	29.0	10.0	19.0
Control carcass (T_c)	12.8	17.0	8.5	8.5
Ambient air (T_a)	12.7	23.8	3.2	20.6
Infested-ambient (T_i-T_a)	8.6	16.9	-7.3	24.2
Control-ambient (T_c-T_a)	0.1	6.3	-9.4	15.7
Infested-control (T_i-T_c)	6.5	15.6	6.1	15.4

Table 4.4c. Summary temperature data for period in spring (days 54-108, inclusive), in which a pig carcass was infested exclusively with larvae of *H. rostrata*, compared with data for an adjacent uninfested pig carcass (control) and the ambient air.

	mean	max.	min.	range
Infested carcass (T_i)	22.4	36.3	14.8	21.5
Control carcass (T_c)	17.8	25.7	13.4	12.3
Ambient air (T_a)	17.4	37.8	7.4	30.4
Infested-ambient (T_i-T_a)	5.0	14.7	-9.3	24.0
Control-ambient (T_c-T_a)	0.4	8.0	-17.1	25.1
Infested-control (T_i-T_c)	4.6	16.5	0.1	16.4

Table 4.5. Summary temperature data for two piglet carcasses infested with blowfly larvae in summer - one exposed to the sun and the other a shaded control, and further control data for uninfested sun-exposed and shaded piglet carcasses, compared with temperatures in the ambient air in the sun and shade. Note that the middle third of this table (for shaded carcasses) is identical to Table 4.2.

		mean	max.	min.	range
Sun-exposed	Infested carcass (T_i)	35.5	61.7	16.4	45.3
	Control carcass (T_c)	36.5	61.7	15.7	46.0
	Ambient air (T_a)	26.5	41.9	13.5	28.4
	Infested-ambient (T_i-T_a)	9.0	24.3	-2.5	26.8
	Control-ambient (T_c-T_a)	10.0	28.5	-2.3	30.8
	Infested-control (T_i-T_c)	-1.0	2.2	-9.4	11.6
Shaded	Infested carcass (T_i)	30.6	40.2	18.0	22.2
	Control carcass (T_c)	25.7	38.5	16.2	22.3
	Ambient air (T_a)	24.4	39.8	12.0	27.8
	Infested-ambient (T_i-T_a)	6.3	12.5	-0.5	13.0
	Control-ambient (T_c-T_a)	1.3	7.4	-8.4	15.8
	Infested-control (T_i-T_c)	5.0	9.3	0.2	9.1
Sun-exposed -shaded	Infested carcass (T_i)	4.9	22.9	-8.6	31.5
	Control carcass (T_c)	10.8	34.4	-2.2	36.6
	Ambient air (T_a)	2.1	6.5	-1.5	8.0
	Infested-ambient (T_i-T_a)	2.7	22.1	-10.8	32.9
	Control-ambient (T_c-T_a)	8.7	32.5	-3.7	36.2
	Infested-control (T_i-T_c)	-6.6	0.8	-17.5	18.3

Table 4.6. Thermal death points (in °C) of third instar larvae of three species of blowfly under two different rates of heating. Given in brackets are the degree-minutes in excess of 25°C during the heating period.

	0.2°C/min.	0.6°C/min.
Calliphora dubia	44 (1805)	45 (667)
Calliphora vicina	46 (2205)	47 (807)
Chrysomya rufifacies	47 (2420)	52 (1215)

Chapter 5

Influence of Ambient Temperature on Activity of Adult Blowflies

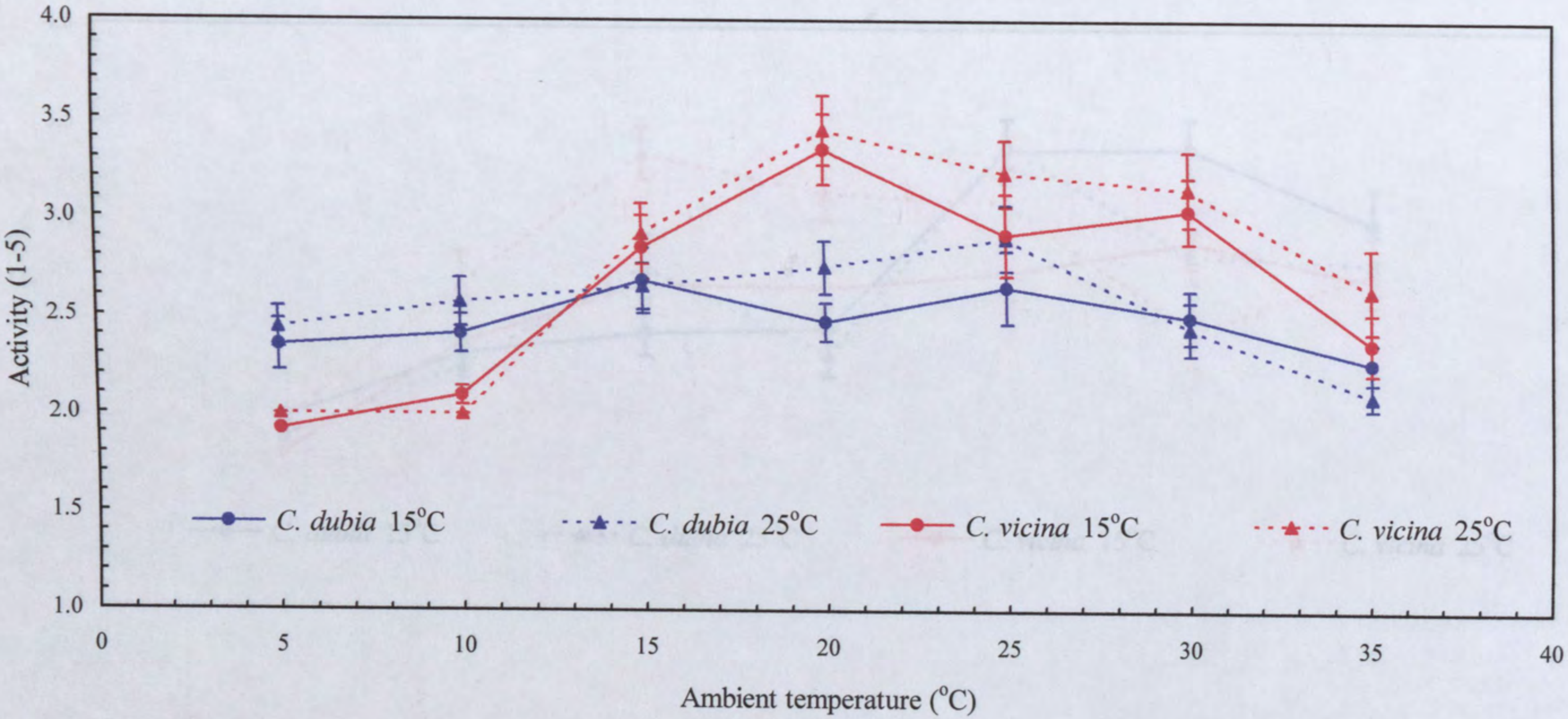


Fig. 5.1. Mean activity (± s.e.) at different ambient temperatures of adult *C. dubia* and *C. vicina* exposed to 15°C and 25°C during maternal egg development, but to 15°C during post-oviposition development (treatments 1 and 2).

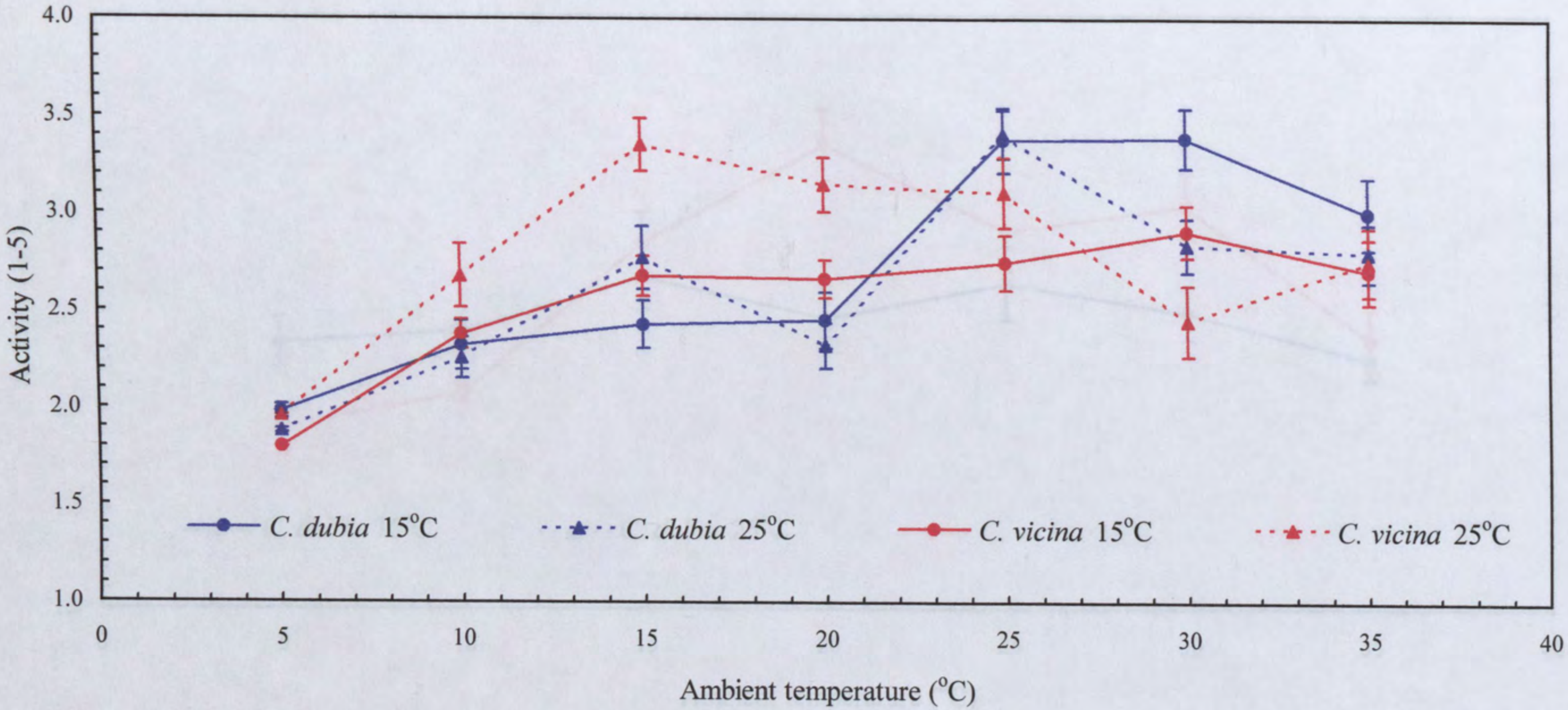


Fig. 5.2. Mean activity (± s.e.) at different ambient temperatures of adult *C. dubia* and *C. vicina* exposed to 15°C and 25°C during maternal egg development, but to 25°C during post-oviposition development (treatments 3 and 4).

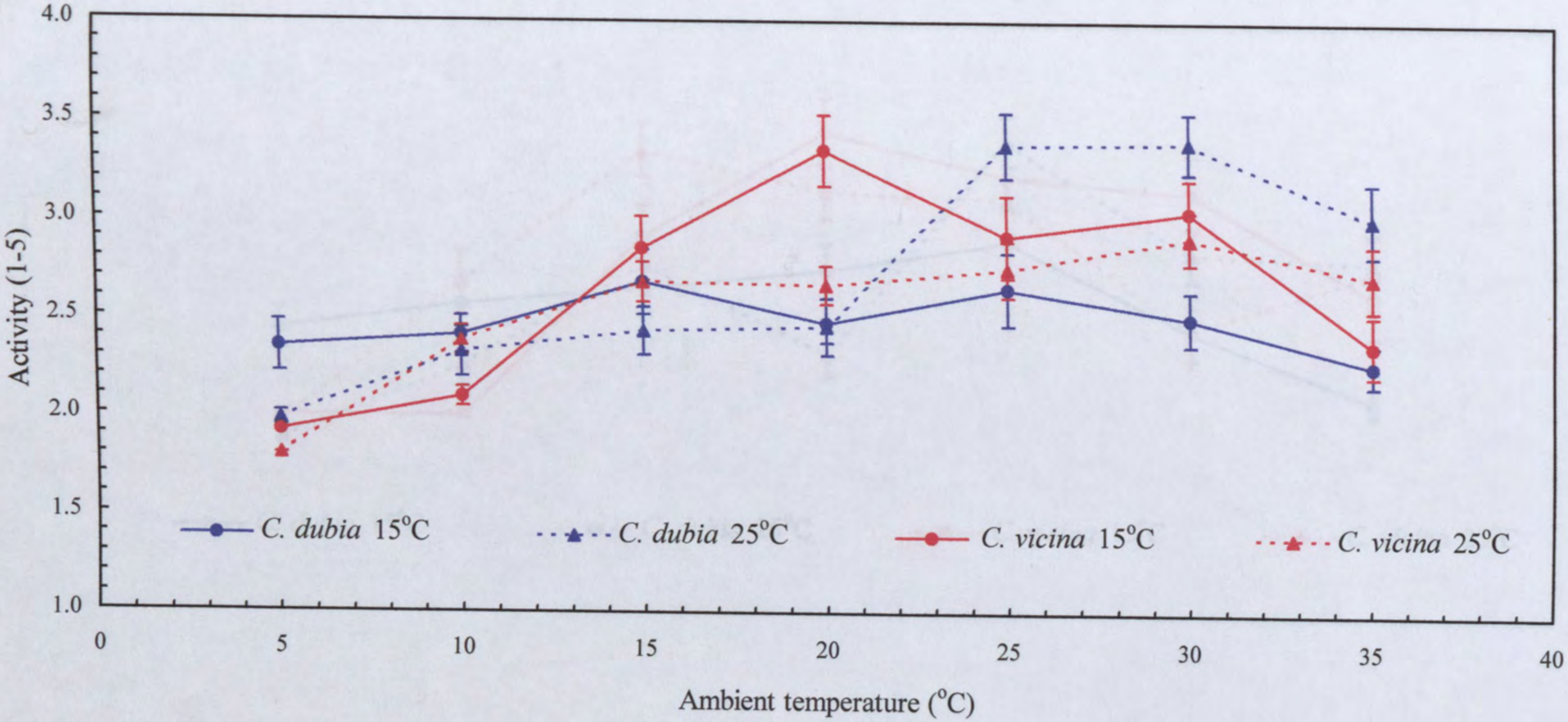


Fig. 5.3. Mean activity (± s.e.) at different ambient temperatures of adult *C. dubia* and *C. vicina* exposed to 15°C and 25°C during post-oviposition development, but to 15°C during maternal egg development (treatments 1 and 3).

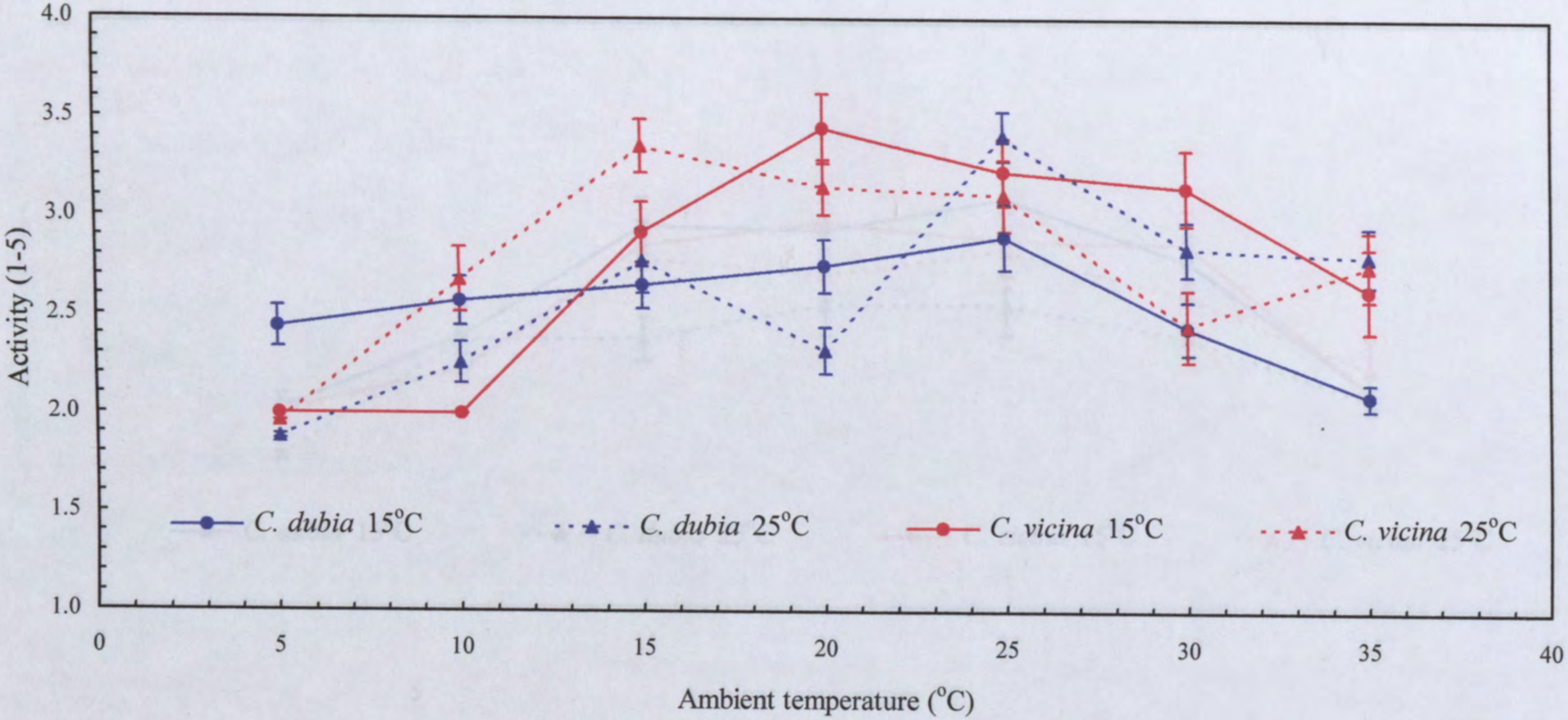


Fig. 5.4. Mean activity (± s.e.) at different ambient temperatures of adult *C. dubia* and *C. vicina* exposed to 15°C and 25°C during post-oviposition development, but to 25°C during maternal egg development (treatments 2 and 4).

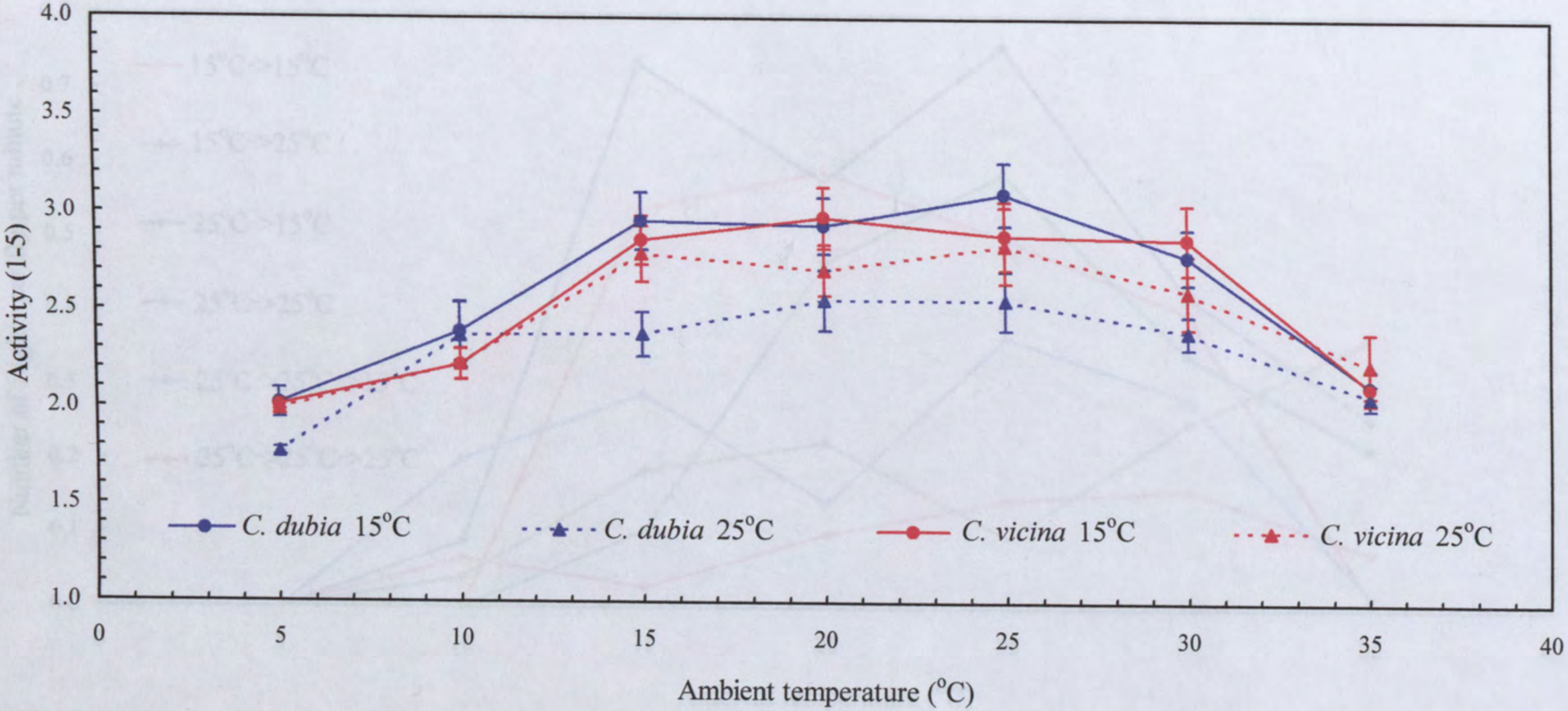


Fig. 5.5. Mean activity (± s.e.) at different ambient temperatures of adult *C. dubia* and *C. vicina* exposed to 15°C and 25°C during the first two weeks of adult life, but to 25°C during all prior maternal and post-oviposition development.

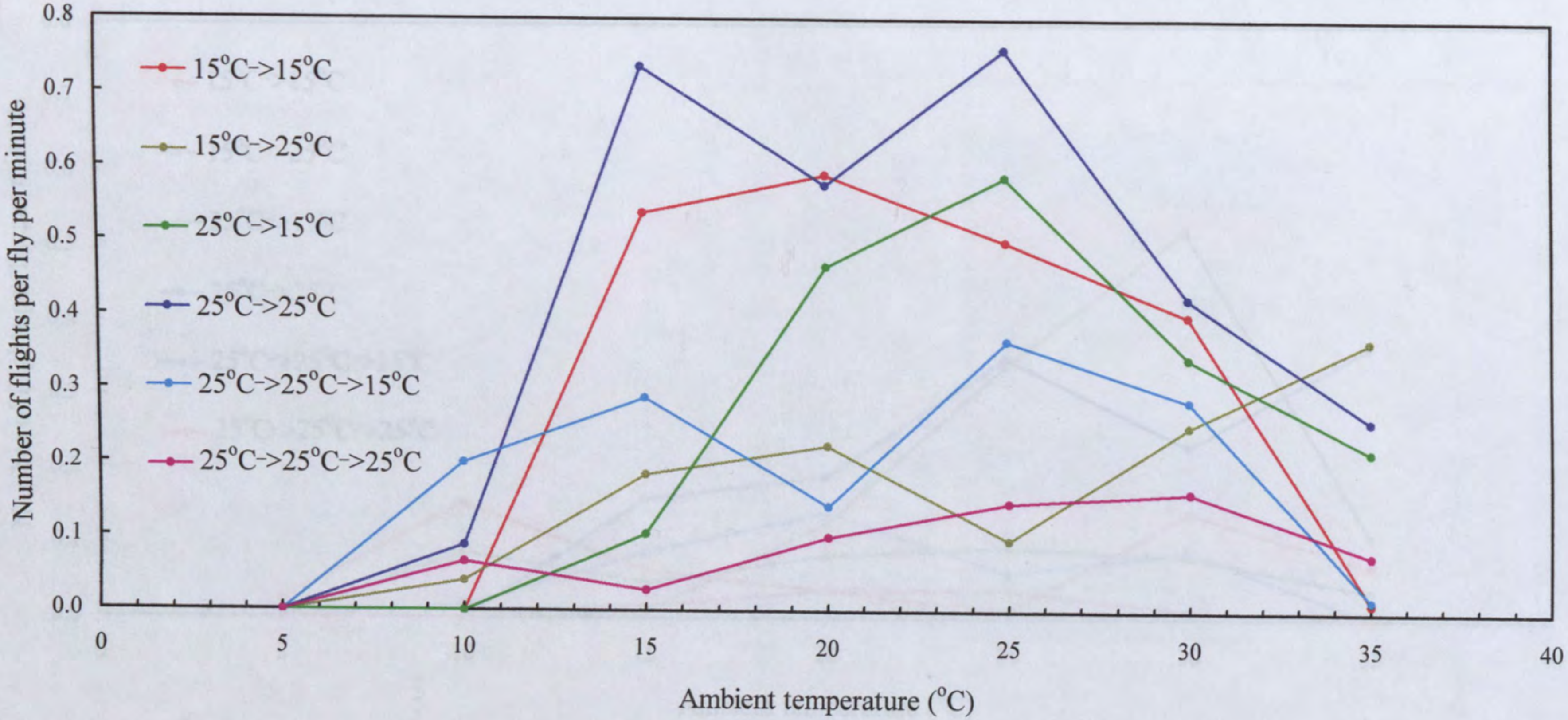


Fig. 5.6. Numbers of flights at different ambient temperatures for individuals of *C. dubia* with six different thermal histories (15°C→15°C, 25°C→15°C, 15°C→25°C and 25°C→25°C concern Experiments 1 and 2, 25°C→25°C→15°C and 25°C→25°C→25°C concern Experiment 3).

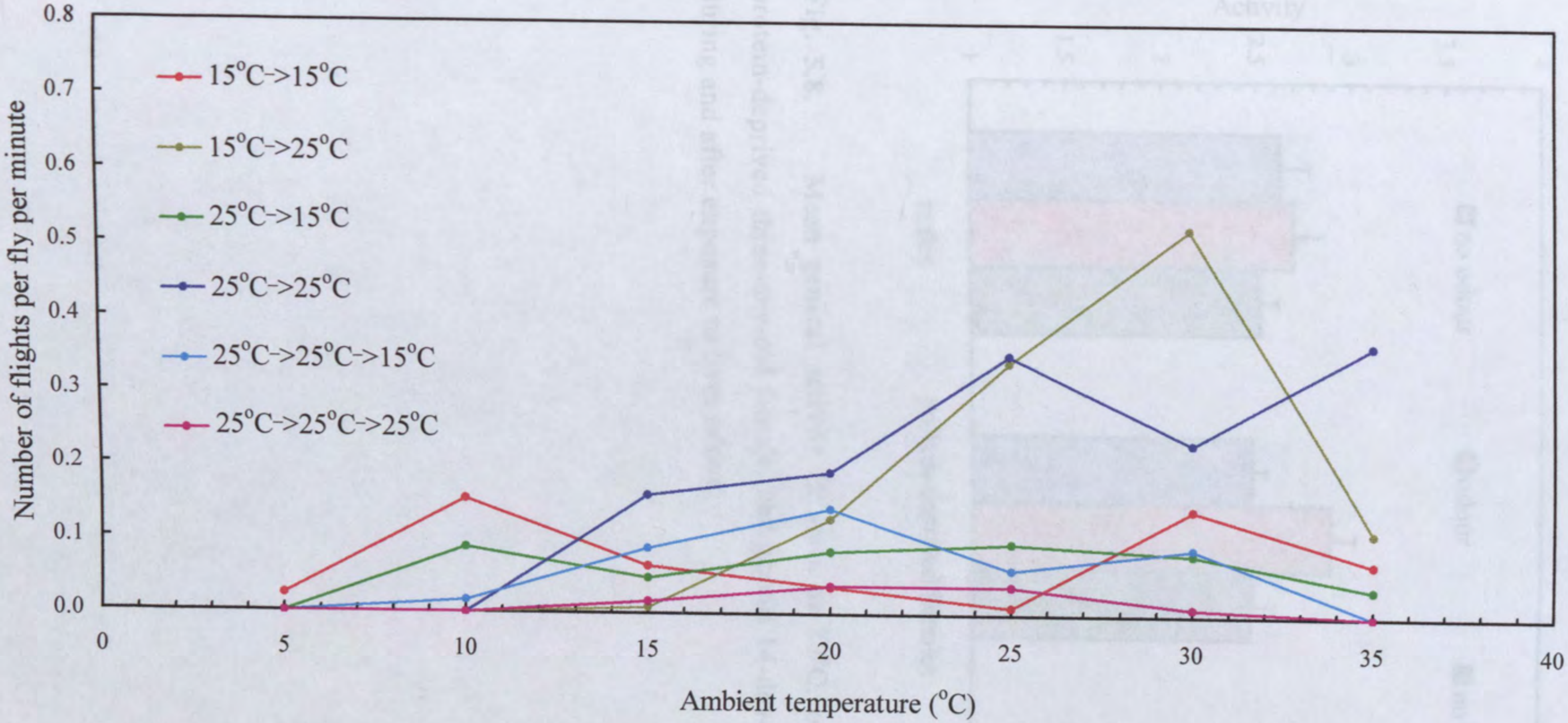


Fig. 5.7. Numbers of flights at different ambient temperatures for individuals of *C. vicina* with six different thermal histories (15°C→15°C, 25°C→15°C, 15°C→25°C and 25°C→25°C concern Experiments 1 and 2, 25°C→25°C→15°C and 25°C→25°C→25°C concern Experiment 3).

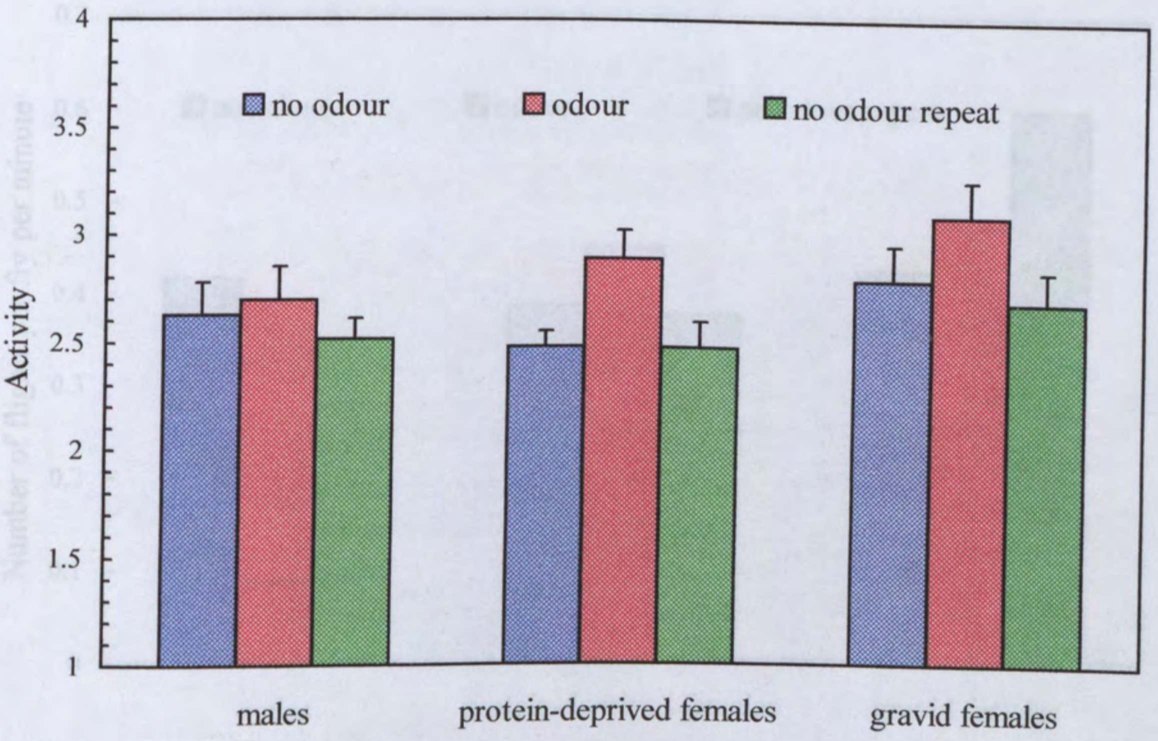


Fig. 5.8. Mean general activity (± s.e.), at 20°C, of three-day old male, protein-deprived three-day-old female, and gravid 14-day-old *C. vicina*, before, during and after exposure to liver odour.

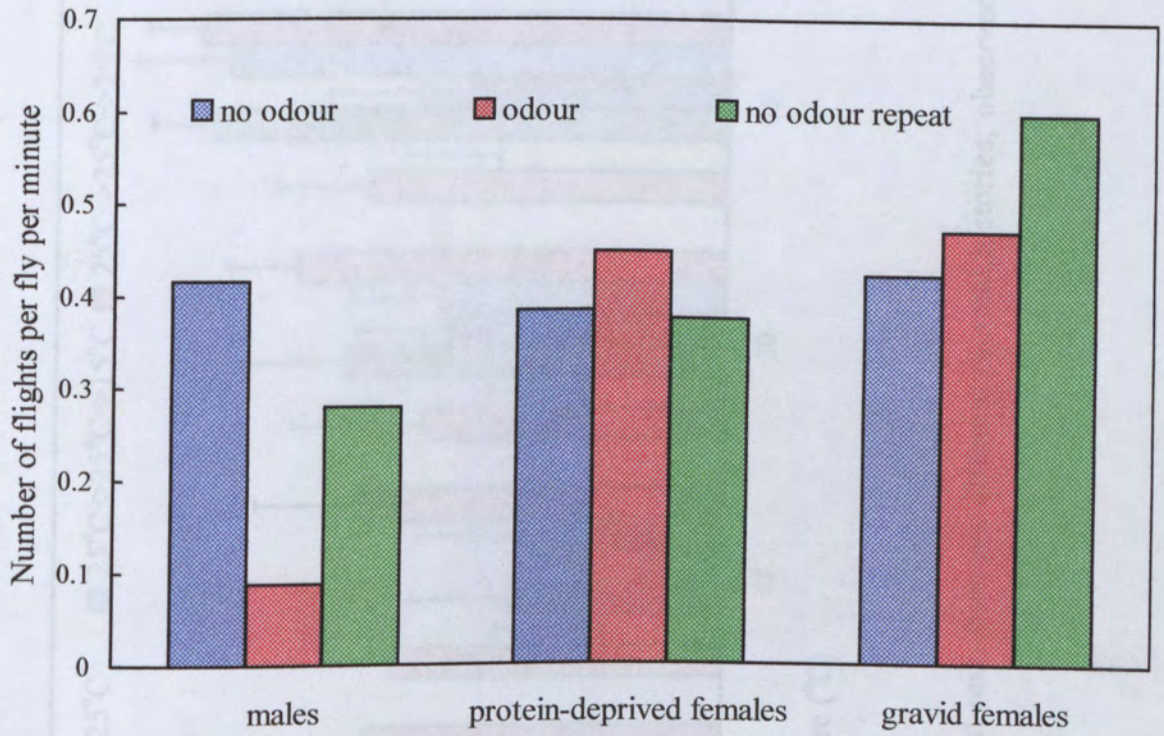


Fig. 5.9. Numbers of flights per fly, at 20°C, of three-day old male, three-day-old female protein-deprived, and 14-day-old gravid *C. vicina*, before, during and after exposure to liver odour.

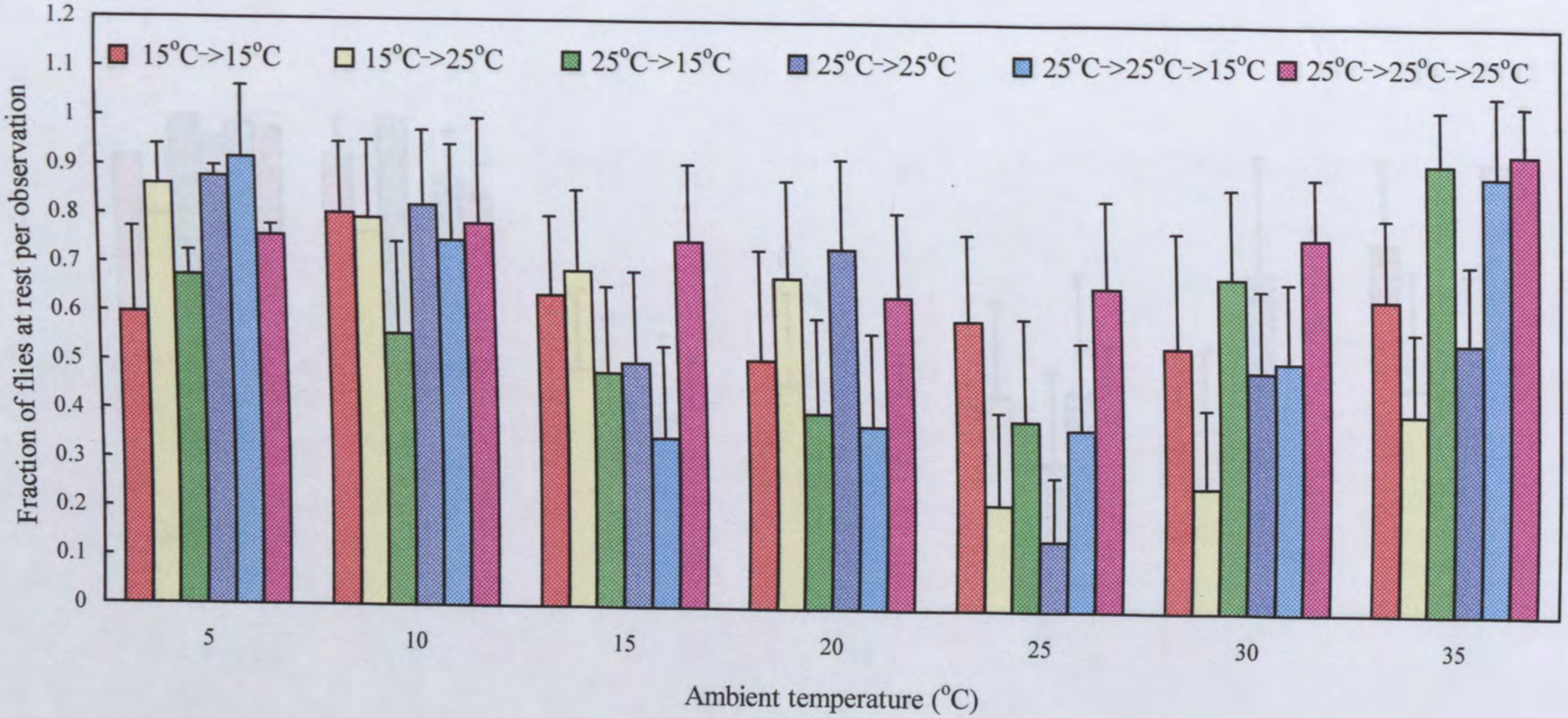


Fig. 5.10. Mean fraction per observation (± s.e.) of adult *C. dubia* at rest, from six different thermal histories, observed at different ambient temperatures.

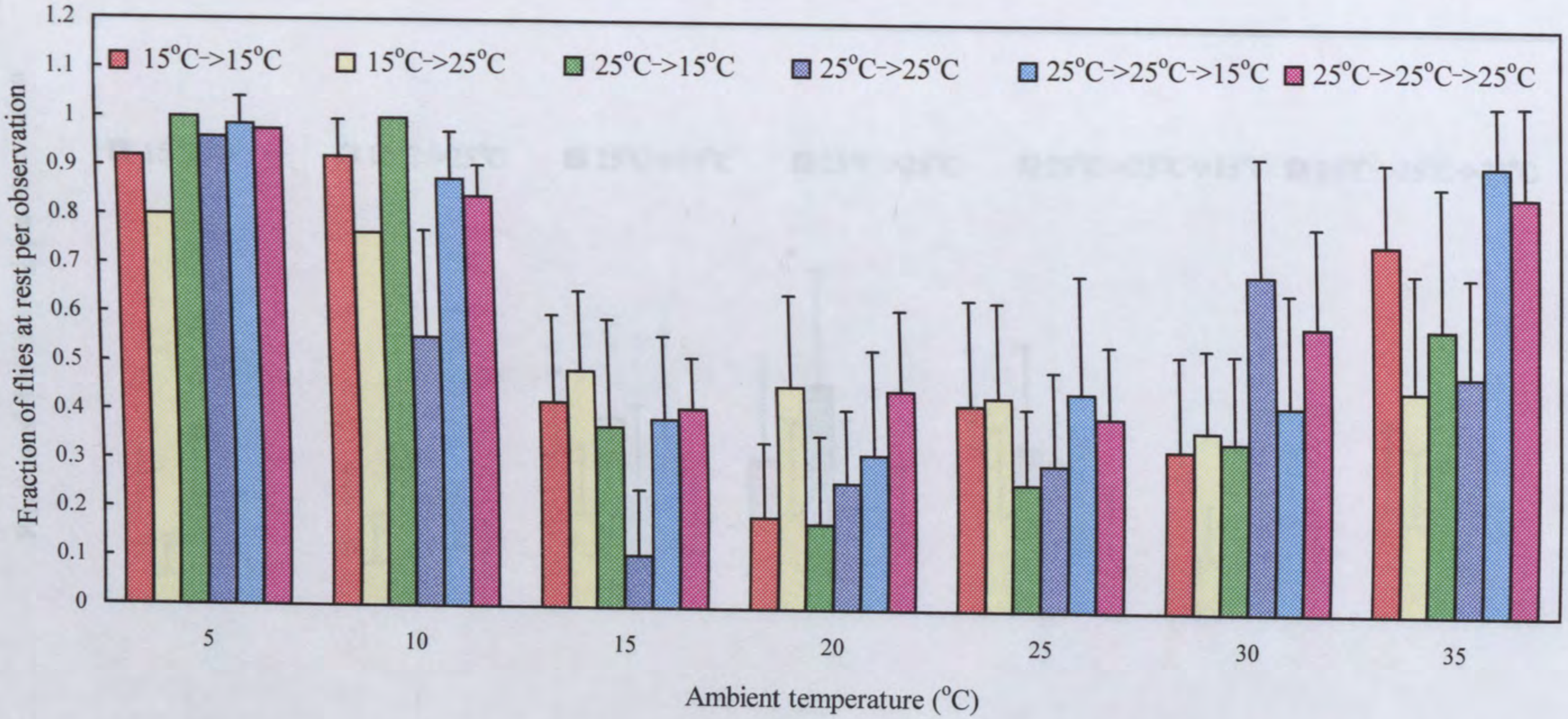


Fig. 5.11. Mean fraction per observation (± s.e.) of adult *C. vicina* at rest, from six different thermal histories, observed at different ambient temperatures.

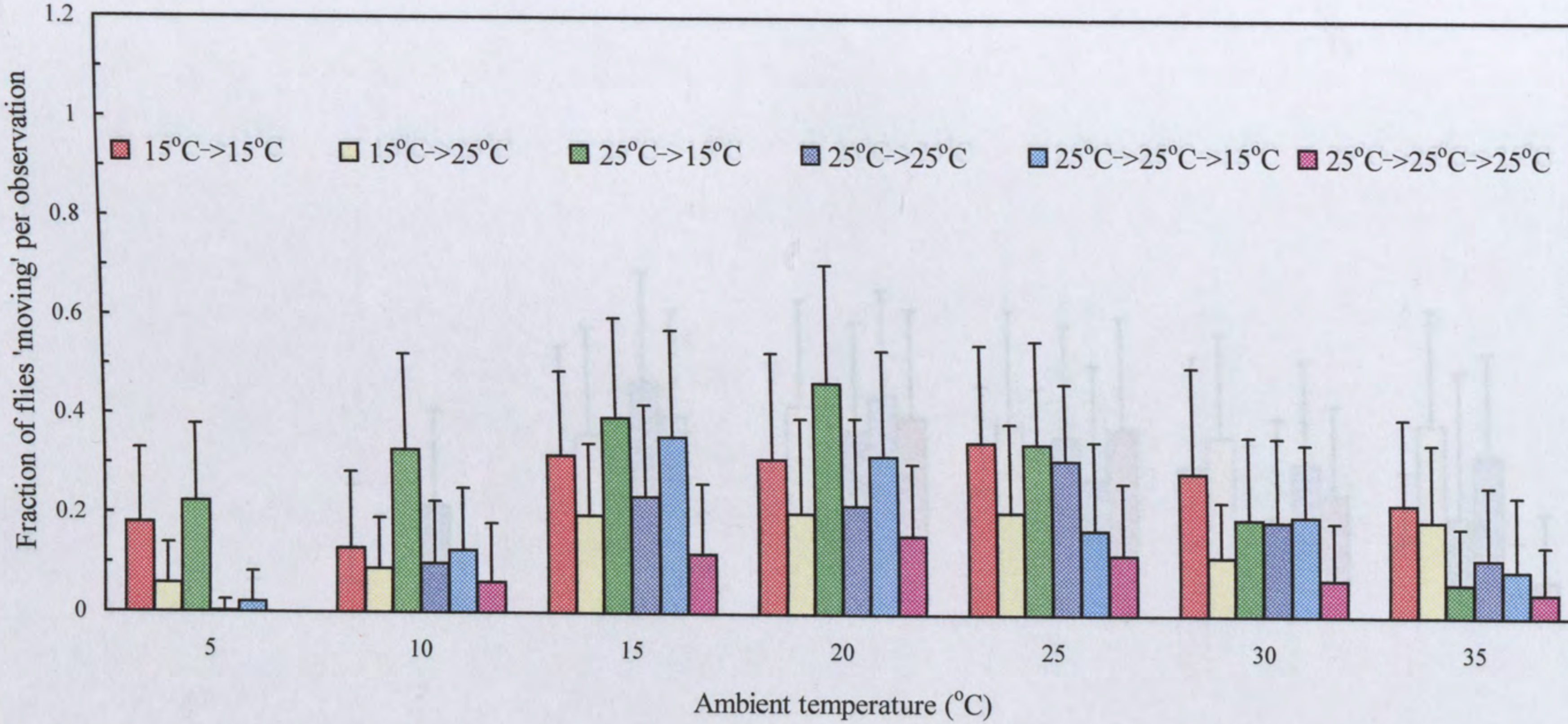


Fig. 5.12. Mean fraction per observation (± s.e.) of 'moving' adult *C. dubia* from six different thermal histories, observed at different ambient temperatures.

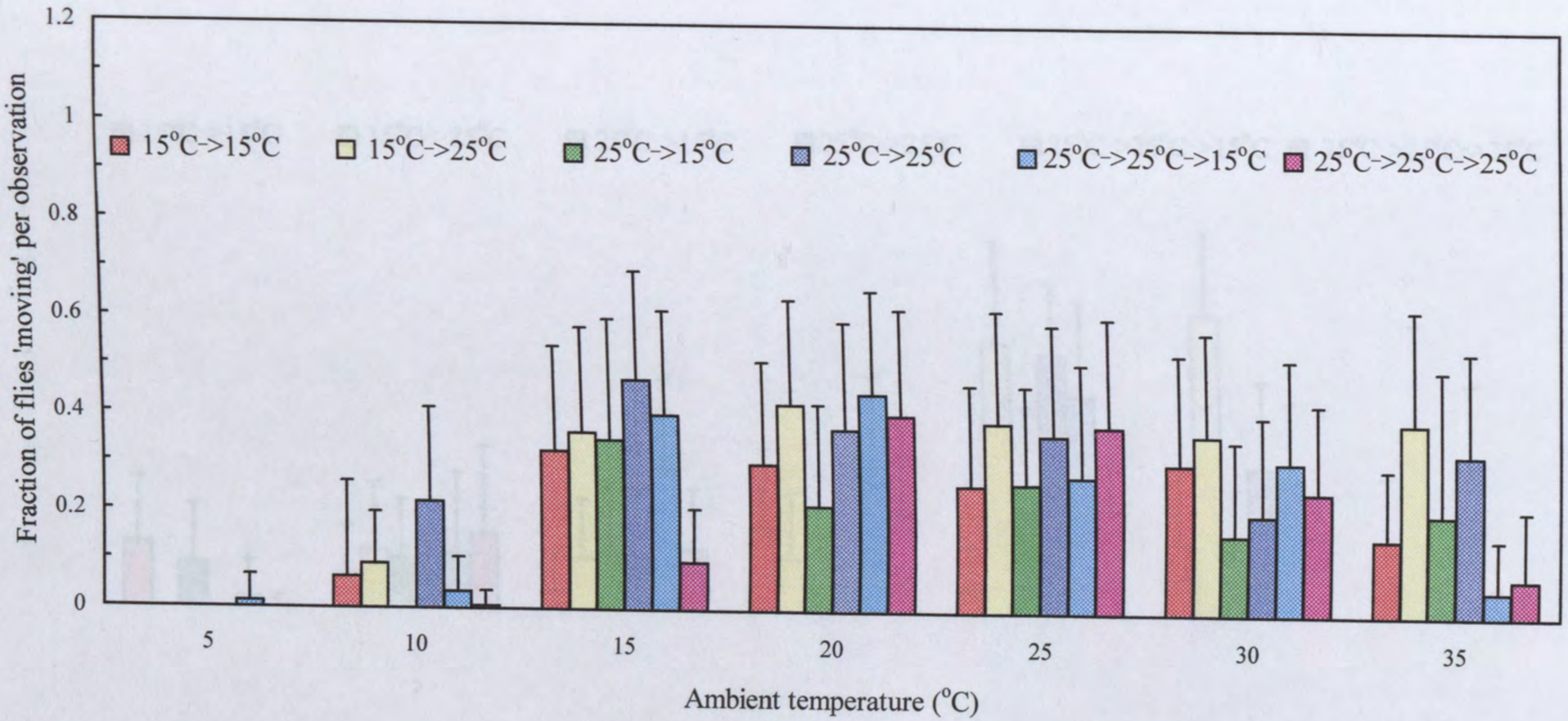


Fig. 5.13. Mean fraction per observation (± s.e.) of 'moving' adult *C. vicina* from six different thermal histories, observed at different ambient temperatures.

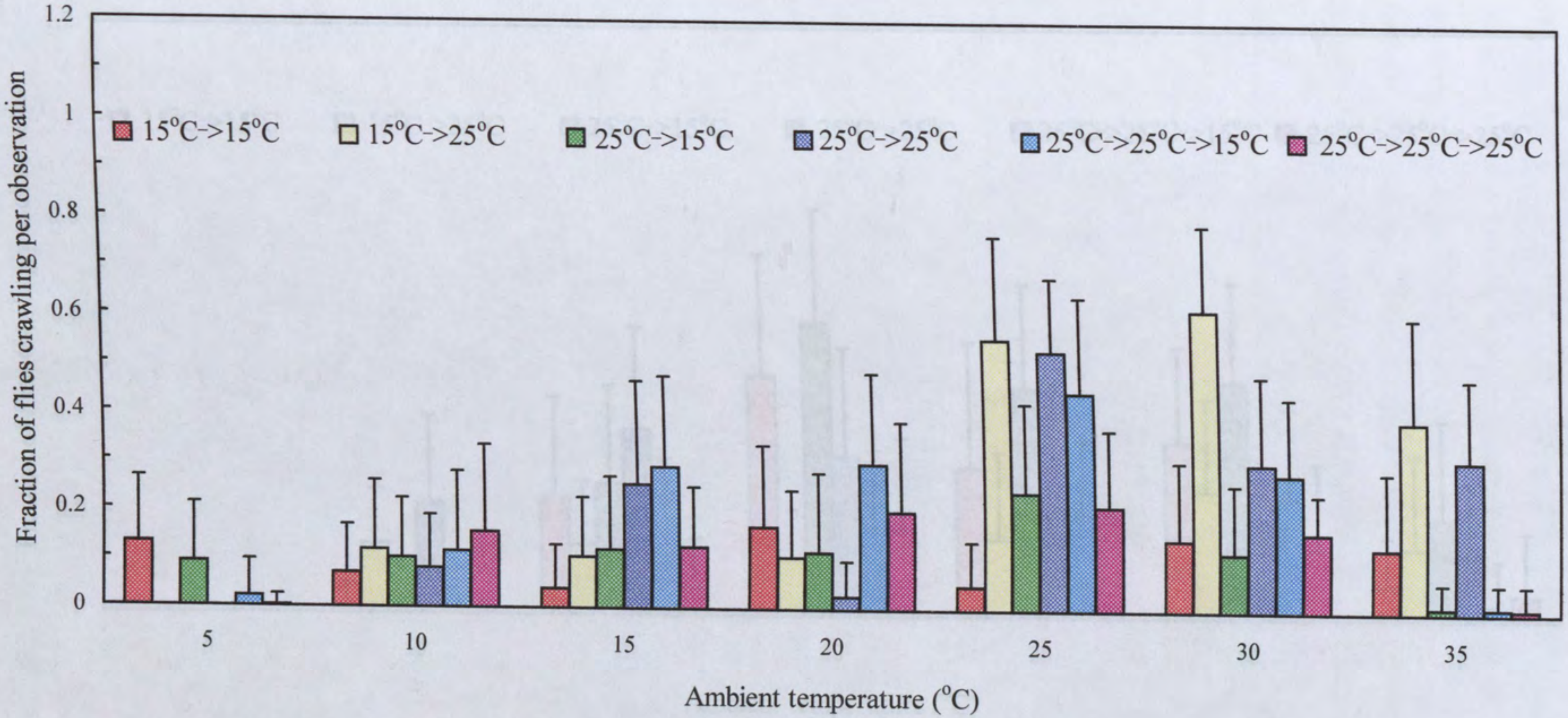


Fig. 5.14. Mean fraction per observation (± s.e.) of crawling adult *C. dubia* from six different thermal histories, observed at different ambient temperatures.

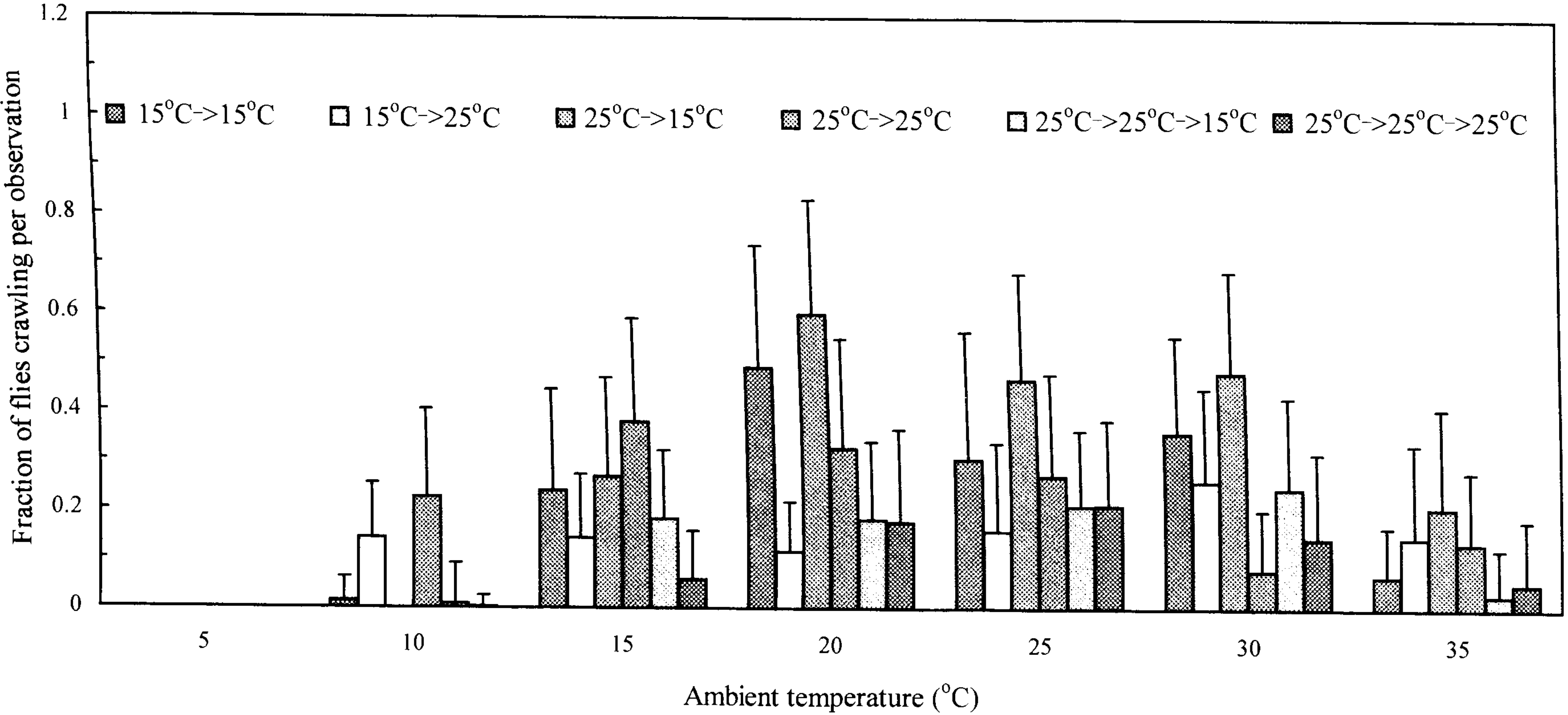


Fig. 5.15. Mean fraction per observation (± s.e.) of crawling adult *C. vicina* from six different thermal histories, observed at different ambient temperatures.

Table 5.1. Ranges of total development time (from oviposition to eclosion), in days, of two blowfly species under four different developmental temperature regimes. The temperature before the arrow is that to which eggs were exposed within the mother. The temperature after the arrow is the post-oviposition temperature: that to which larvae and pupae were exposed.

	C. dubia	*C. vicina*
15°C→15°C	42-46	32-38
25°C→15°C	32-39	32-41
15°C→25°C	15-17	16-19
25°C→25°C	16-18	17-18

Table 5.2. Mean fraction per observation (± s.e.), at 5°C, of comatose adult *C. dubia* and *C. vicina* from six different thermal histories.

	C. dubia	*C. vicina*
15°C→15°C	0.092 ± 0.004	0.08
25°C→15°C	0.08	0.2
15°C→25°C	-	-
25°C→25°C	0.12	0.04
25°C→25°C→15°C	0.04	-
25°C→25°C→25°C	0.24	0.016 ± 0.003

Appendix A

Associated Observations

During the course of the work for this thesis miscellaneous observations were made that do not relate to the thesis directly, but which are important nonetheless. Some of these observations have been published (papers given in Appendix B).

New distribution records

During the course of this work I frequently trapped flies in a liver-baited trap on the grounds of the North Terrace campus of the University of Adelaide. These collections provided specimens for the systematic work and for establishing colonies for the biological studies. The collections yielded two species that had not previously been recorded from South Australia, *Calliphora nigrithorax* Hardy and *Chrysomya megacephala* (Fabricius).

New habitat record

The above collections also yielded specimens of *Calliphora maritima*. As mentioned in Chapter 1, this species is characteristically restricted to littoral habitats. It was therefore surprising to find it in the centre of Adelaide, a minimum of approximately five kilometres from the sea. This is an important observation forensically, because if a body discovered inland was found to contain larvae of this species, it would usually suggest that the body had initially been infested by the sea and had subsequently been moved. My observation indicates that caution should be applied in making inferences.

It is not known to which features of the littoral environment *Calliphora maritima* is adapted; this would be a useful line of future enquiry.

Insects other than flies at carrion

While carrying out the studies on blowflies infesting pig carrion in Chapter 5, general observations were also made of other prominent insects attracted to the carcasses.

Collembola

During the winter-spring large carcass experiment (Experiment 4) huge numbers of Collembola were observed on the carcasses after rain had fallen. I observed the same phenomenon in earlier work on piglet carcasses in winter (Wallman 1990).

Beetles

Beetles were prominent during the winter-spring large carcass experiment (Experiment 4). Particularly common were *Creophilus erythrocephalus* Fabricius (Staphylinidae) and a species of *Saprinus* (Histeridae), both of which preyed on blowfly larvae. These species were also observed during the autumn study (Experiment 3). Two other prominent species in Experiment 4 were *Aleochara brachialis* Jekel and *Aleochara speculifera* Erichson (Staphylinidae). Larvae and adults of *Dermestes frischii* Kugelann (Dermestidae) were abundant on the carcass when it had been reduced to bone and dry skin.

Wasps

European wasps (*Vespula germanica* (Fabricius)) were abundant thoughout the autumn large carcass experiment (Experiment 3). They stung and carried off adult blowflies that were feeding or ovipositing on the carcass, thus influencing levels of infestation. Wasps continued to be active during cool or overcast weather that otherwise noticeably reduced the activity of blowflies. I have already mentioned the likely influence of parasitoid wasps on the physiology of blowfly larvae (Section 4.1). Both these parasitoid and European wasps might at times affect infestations of carcasses in their different ways.

Appendix B

Associated Publications

The following papers either directly concern material discussed in the body of the thesis or relate to peripheral observations made during the course of the work:

- Wallman, J. F. (1993). First South Australian record of the carrion-breeding blowfly *Calliphora nigrithorax* Malloch. *Transactions of the Royal Society of South Australia* **117**, 193.

- Wallman, J. F. (1997). First record of the Oriental Latrine Fly, *Chrysomya megacephala* (Fabricius) (Diptera: Calliphoridae), from South Australia. *Transactions of the Royal Society of South Australia* **121**, 163-164.

- Wallman, J. F., and Adams, M. (1997). Molecular systematics of carrion-breeding blowflies of the genus *Calliphora* (Diptera: Calliphoridae). *Australian Journal of Zoology* **45**, 337-356.

Wallman, J. F. (1993). First South Australia record of the carrion-breading blowfly Calliphora Nigrithoraz Malloch (Diptera: Calliphoridae). *Transactions of the Royal Society of South Australia, 117*(4), 193.

NOTE:

This publication is included in the print copy
of the thesis held in the University of Adelaide Library.

Wallman, J. (1997). First record of the oriental latrine fly, Chrysomya megacephala (Fabricius) (Diptera: Calliphoridae), from South Australia. *Transactions of the Royal Society of South Australia, 121*(4), 163-164.

NOTE:

This publication is included in the print copy
of the thesis held in the University of Adelaide Library.

Wallman, J. F., & Adams, M. (1997). Molecular Systematics of Australian Carrion-breeding Blowflies of the Genus Calliphora (Diptera: Calliphoridae). *Australian Journal of Zoology*, *45*(4), 337-356.