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Prevalence of *Aedes camptorhynchus* (Thomson) (Diptera: Culicidae) and Other Mosquitoes in the Eastern Coast of Victoria

K. DHILEEPAN[1], C. PETERS[2] and A. PORTER[3]

Victorian Institute of Animal Science, Attwood, Vic. 3049.
[1]Present address: Tropical Weeds Research Centre, P.O. Box 187, Charters Towers, Qld 4820.
[2]Present address: P.O. Box 4, Lake Bolac, Vic. 3351.
[3]Infectious Diseases Section, Victorian Dept Health and Community Services.

ABSTRACT Adult mosquito populations were monitored using dry-ice baited EVS light traps at weekly intervals for four seasons (1991-95) in Avon, Bairnsdale, Rosedale and Hastings, and for three seasons (1991-94) in Tambo, in the eastern coast of Victoria. Among the 20 species of adult mosquitoes recorded, *Aedes camptorhynchus* (Thomson) was dominant (74-99%). Higher *Ae camptorhynchus* adult populations were recorded in the 1992-93 and 1993-94 seasons, than in 1991-92 and 1994-95 seasons. Rosedale shire recorded higher *Ae camptorhynchus* adult populations than the Avon, Bairnsdale, Hastings and Tambo shires. In all shires, two peaks of *Ae camptorhynchus* activity reaching high (100-1,000 adults/trap) to very high (> 1,000 adults/trap) levels were recorded, with the first peak in the middle of December (summer) and the second peak in the middle of April (autumn). The *Ae camptorhynchus* activity in the coastal region increased with an increase in the minimum temperature.

Introduction

The Ross River (RR) and Barmah Forest (BF) viruses are the most common and widespread arboviruses of public health importance in Victoria, and are endemic in the riverine Murray valley and coastal Gippsland regions (Vitarana *et al.* 1992). *Culex annnulirostris* Skuse and *Aedes camptorhynchus* (Thomson) are implicated as major vectors of both RR and BF viruses in the Murray Valley and coastal regions, respectively (Mackenzie *et al.* 1994; Russell 1995). Knowledge of the major mosquito vectors and environmental parameters which are conducive to mosquito breeding and abundance are essential for predicting arboviral epidemics (Mackenzie *et al.* 1994). Such information is vital for forecasting future disease outbreaks, as well as for planning arbovirus disease control operations. Information on the species composition and prevalence of adult mosquitoes in Victoria is widely available with specific reference to the Murray valley region (Dhileepan 1996; Marshall *et al.* 1982; McDonald 1980; Russell 1986a,b). However, in the eastern coastal region, except for limited information on adult mosquitoes in Avon shire for one year (Campbell *et al.* 1989a), no information is available on the species composition and population trends. Our study reports the results of arbovirus vector surveillance carried out in five shires in the eastern coast.

Materials and methods

Study areas. In the eastern coast of Victoria, along the Gippsland lake system, periodic tidal inundation produce vast expanses of suitable brackish water habitats for mosquito vectors, often resulting in outbreaks of RR and BF diseases. Adult mosquito monitoring was conducted in the following five shires: Avon (147°04'E, 38°07'S), Bairnsdale (147°35'E, 37° 50'S), Hastings (145°11'E, 38°19'S), Rosedale (147°36'E, 38°03'S) and Tambo (147°59'E, 37° 52'S) (Fig. 1).

Monitoring methods. Adult mosquito populations were monitored by setting dry-ice baited encephalitis vector surveillance (EVS) suction light traps before sunset and retrieving the traps soon after sunrise the following morning. In each shire, four traps were set 1.5-2 m above ground level (hung in trees) near potential breeding sites which were within a 10 km zone radiating from the centre of the major residential region. In all the five shires, the same trapping sites were used during the study period. In each season, traps were operated at weekly intervals from the end of spring (first week of November = week 1) to mid-autumn (fourth week of March = week 22), with some shires continuing the trapping during April (up to 26 weeks) if the mosquito population was high. In all shires, attempts were made to set traps in all weeks, during all the four seasons. However, due to heavy rains, windy conditions, storms, damage by cattle and missing traps, adult trapping could not be carried out in some of the weeks. Adult mosquito populations were monitored for 83, 80, 65 and 89 weeks in Avon, Bairnsdale, Hastings and Rosedale shires, respectively, during the four annual seasons (1991-92 to 1994-95). In Tambo, monitoring was conducted only for 55 weeks in three annual seasons (1991-92 to 1993-94). In each participating shire, the Environmental Health Officer (EHO) and the mosquito monitor involved in the arboviral vector surveillance program identified the mosquitoes, following the key proposed by Russell (1993). Total number of mosquitoes trapped, species composition, relative abundance of individual species, total weekly rainfall, and maximum, minimum and average temperatures were recorded for each shire.

Statistical analysis. The number of mosquito species collected (species diversity) in all four trapping sites in each shire was compared between shires, as well as between seasons in each shire, using two-way Analysis of Variance (ANOVA) and Student-Newman-Keuls methods. Variations in the average number of *Ae camptorhynchus*/trap (mean of four traps), between shires and between seasons were also analysed by the same two methods. Impact of four meteorological factors (maximum temperature, minimum temperature, mean temperature and total weekly rainfall) on dependent variables (abundance of *Ae camptorhynchus* and other mosquito species) was analysed using linear and polynomial regression methods. For regression analysis, data pooled from all the five shires (N = 372), as well as from individual shires (Avon = 83, Bairnsdale = 80; Hastings = 65; Rosedale = 89 and Tambo = 55) were used.

Results

Species composition. A total of 428,298 adult mosquitoes comprising 20 species (Table 1) was recorded in 20 trapping sites in five shires in the eastern coast of Victoria, during the four seasons (1991-92 to 1994-95). Only 561 males (0.13%) were recorded among the collections, so the following data refer almost exclusively to females. The species diversity varied between shires as well as between trap sites in each. However, there was no significant difference in the number of species trapped between years in each trapping site. The highest number of mosquito species (19) was reported from Hastings shire, while in other shires the number of mosquito species recorded ranged from 10 to 13 (Table 1). Adult mosquitoes which could not be identified due to damage or other reasons were considered as "others (spp. indet.)" and were not included in the species diversity. In all the shires, *Ae camptorhynchus* was the dominant species comprising 74-99% of the seasonal total. Again, the frequency of *Ae camptorhynchus* adults trapped varied significantly between shires as well as between seasons in each shire. In Rosedale shire, even though 13 species of mosquitoes were recorded, *Ae camptorhynchus* constituted 95.6-98.9% of the total mosquitoes trapped, while in other shires it ranged from 73.7 to 86.9% (Table 1). At least 5 of the 12 species in Avon and 6 of 11 species in Bairnsdale occurred consistently in all the four seasons. In Hastings, 6 of 19 species were trapped regularly in all the four seasons, while in Rosedale, only 3 of 13 species were trapped consistently. In Tambo, 5 of 10 species of mosquitoes were trapped consistently in all the three seasons. Mosquito species other than *Ae camptorhynchus* consistently recorded in these shires include *Cx australicus* Dobrotworsky and Drummond

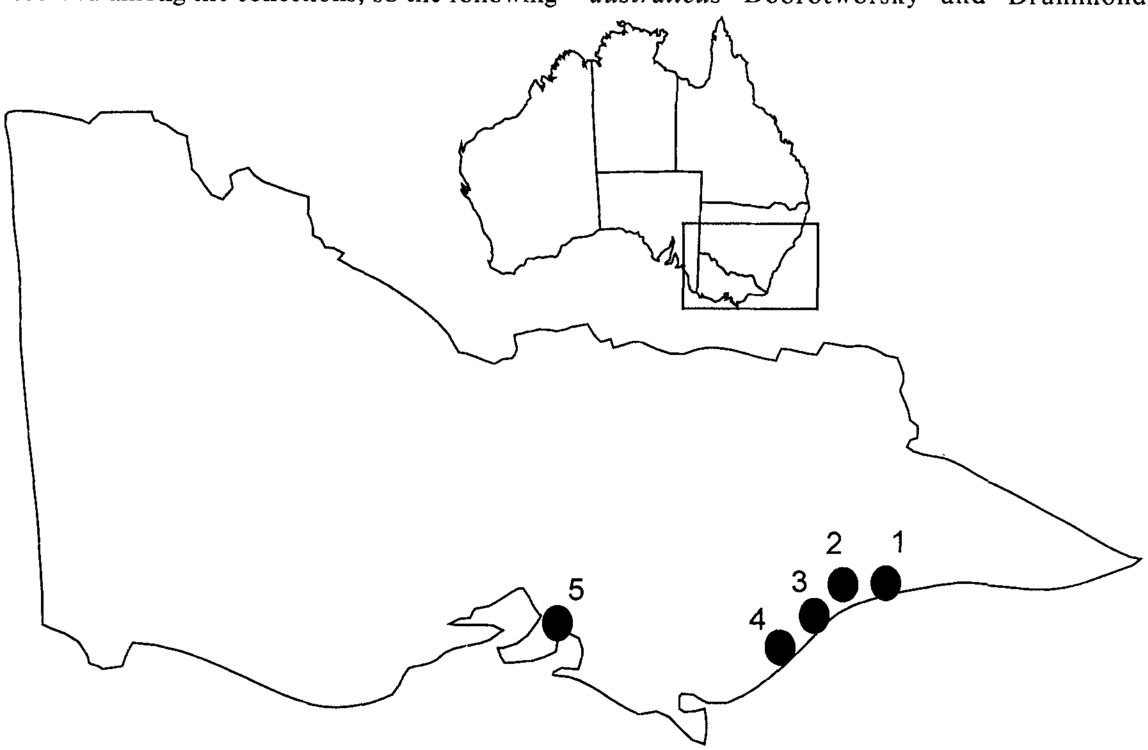

Fig. 1. Monitoring sites of adult mosquitoes in Victoria. Solid circles represent shires in the coastal region: 1 = Tambo, 2 = Bairnsdale, 3 = Avon, 4 = Rosedale and 5 = Hastings.

(0.09-6.89%), *Anopheles annulipes* Walker (0.02-3.74%), *Cx globocoxitus* Dobrotworsky (0.07-6.07%) and *Coquillettidia linealis* (Skuse) (0.08-11.64%).

***Aedes camptorhynchus* population.** The average number of *Ae camptorhynchus* collected/trap/night in each season, varied considerably between seasons ($F = 3.98$; $df = 3$, $P = 0.038$) as well as between shires ($F = 4.79$, $df = 4$, $P = 0.017$) (Fig. 2). Rosedale recorded the highest *Ae camptorhynchus* adult population (645 ± 230 SE), followed by Avon (275 ± 70 SE), Bairnsdale (128 ± 44 SE), Hastings (118 ± 38 SE) and Tambo (96 ± 45 SE). In general, 1992-93 (335 ± 122 SE) and 1993-94 (472 ± 187 SE) seasons recorded higher *Ae camptorhynchus* populations ($P < 0.05$) than the 1991-92 (112 ± 43 SE) and 1994-95 (79 ± 28 SE) seasons (Fig. 2). There was no significant difference ($P > 0.05$) in the average number of *Ae camptorhynchus* adults collected/

Table 1. Species composition and abundance of adult mosquitoes trapped in four traps per season for four seasons in five shires in the eastern coast of Victoria.

Mosquito species	Avon					Bairnsdale					Hastings				
	1991/ 1992	1992/ 1993	1993/ 1994	1994/ 1995	Mean %	1991/ 1992	1992/ 1993	1993/ 1994	1994/ 1995	Mean %	1991/ 1992	1992/ 1993	1993/ 1994	1994/ 1995	Mean %
Ae alboannulatus		2									83	13	68		0.35
Ae alternans						4	10	42	1	0.04			3	1	0.02
Ae bancroftianus												27		2	0.06
Ae camptorhynchus	7,788	32,914	32,725	11,004	79.06	4,044	15,738	19,486	1,976	85.86	3,567	12,939	16,962	1,447	73.70
Ae flavifrons													118		0.25
Ae multiplex			3	57	0.06										
Ae notoscriptus	8	42	40	54	0.13	21	54	54	268	0.15	17	296	224	170	1.49
Ae rubrithorax													68	1	0.16
Ae vittiger											4				
An annulipes	117	3,110	683	82	3.74	9	99	80	6	0.40	4	41	240	7	0.62
Cx annulirostris		2	41		0.04	5	58	68	3	0.14	20		4		0.05
Cx australicus	298	1,623	139	106	2.03	263	1,390	308	84	4.21	545	1,065	787	87	5.24
Cx cylindricus												8		90	0.21
Cx globocoxitus	12	4,053		2,413	6.07				316	0.66		179		211	0.82
Cx molestus	220	252		567	0.97				42	0.09	13	169		78	0.56
Cx orbostiensis									2		12				0.03
Cx pipiens gp.		3,247	2,464		5.35	23	2,885	411		6.91	214	85	723	2	2.16
Cx quinquefasciatus	102		2		0.09						2	5		1	0.02
Cq linealis	3	10	32	38	0.08	1		70	16	0.18	5	788	3,115	1,606	11.64
Cu inconspicua													2		
Others (spp. indet.)						73			1		6	143	6	238	0.83
Males (spp. indet.)	51		12	159	0.21	19	74	29	48	0.35	12	55	9	62	0.29
Total	8,599	45,253	36,141	14,480		4,462	20,308	20,548	2,763		4,507	15,813	22,329	4,003	
Adults/trap	178.5	538.8	477.9	166.4		58.1	253.9	244.6	40.6		86.5	219.6	274.3	62.7	

Table 1. *continued*

Mosquito species	Rosedale					Tambo			
	1991/ 1992	1992/ 1993	1993/ 1994	1994/ 1995	Mean %	1991/ 1992	1992/ 1993	1993/ 1994	Mean %
Ae alboannulatus		3	25	2	0.010	2			
Ae alternans				63	0.030				
Ae bancroftianus				2					
Ae camptorhynchus	11,162	67,236	108,454	13,471	98.96	1,268	4,809	14,498	86.89
Ae flavifrons									
Ae multiplex									
Ae notoscriptus	283	255	213	252	0.510	63	213	106	1.61
Ae rubrithorax									
Ae vittiger				2				7	0.03
An annulipes	10	11	4	8	0.120	58	8	62	0.54
Cx annulirostris									
Cx australicus		50	94	39	0.090	163	766	704	6.89
Cx cylindricus									
Cx globocoxitus		121		23	0.070	94			0.39
Cx molestus	55	247		103	0.200	20			0.08
Cx orbostiensis									
Cx pipiens gp.			157	67	0.110		35	2	0.16
Cx quinquefasciatus				7					
Cq linealis		2			0.001	130	353	311	3.35
Cu inconspicua									
Others (spp. indet.)				1		7	1		0.03
Males (spp. indet.)	5	5		9		12			0.05
Total	11,515	67,930	108,947	14,049		1,817	6,185	15,690	
Adults/trap	261.7	849.1	1,296.9	159.6		25.1	85.9	217.9	

trap, between the 1991-92 and 1994-95 seasons and the 1992-93 and 1993-94 seasons. However, both 1991-92 and 1994-95 seasons differed significantly ($P < 0.05$) from 1992-93 and 1993-94 seasons. The *Ae camptorhynchus* adult population in Rosedale was significantly higher ($P < 0.05$) than in Avon, Bairnsdale, Hastings and Tambo shires. There was no significant difference ($P > 0.05$) in the average number of *Ae camptorhynchus* adults collected/trap between Avon, Bairnsdale, Hastings and Tambo shires.

Two peaks of mosquito activity reaching high (100-1,000 adults/trap) to very high (<1,000 adults/trap) levels were recorded during each season (Fig. 3) in the five shires. The first peak in population numbers was recorded in the middle of December and the second peak in the middle of April. During the rest of the season, mosquito activity remained at medium (50-100 adults/trap) to low (>50 adults/trap) levels. In all the shires, during most of the seasons, the peak mosquito activity was due to increased numbers of *Ae camptorhynchus* (Fig. 3). However, in Avon and Bairnsdale the second peak in mosquito activity during the 1992-93 season was due to the increased activity of both *Ae camptorhynchus* and *Cx australicus*. In Hastings, during the 1994-95 season *Cq linealis* and *Cx australicus* were the predominant species from the first week of January for the rest of the season.

Meteorological factors. The eastern coastal region of Victoria experienced a severe to serious rainfall deficiency in 1991-92 and 1994-95 seasons, while the 1992-93 and 1993-94 seasons received above average rainfall. The *Ae camptorhynchus* population which comprised 85% of the total mosquito population showed a linear positive interaction (Fig. 4) with the minimum temperature in all the five coastal shires. A linear regression, using pooled ($N = 372$) data from all the five shires indicated that the log abundance of *Ae camptorhynchus* was best correlated with the

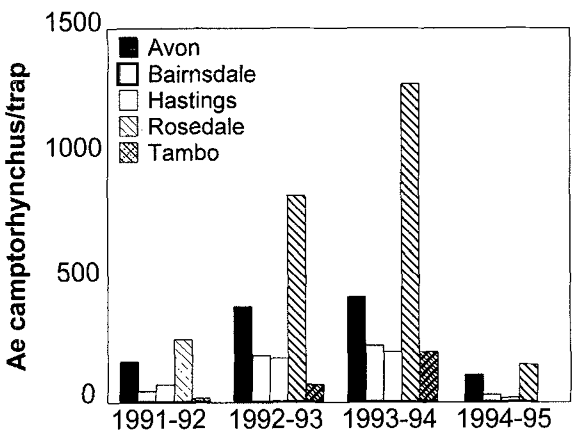

Fig. 2. Abundance of *Ae camptorhynchus* adults/trap in relation to locations (shires) and seasons (1991-1995) in the eastern coast of Victoria.

minimum temperature ($F = 22.5$, $R^2 = 0.23$, $P = <0.001$), while there were no correlations with maximum ($F = 1.39$, $P = 0.24$) and average temperatures ($F = 0.097$, $P = 0.76$). In Avon, the *Ae camptorhynchus* population (average number of adults trapped/night) could be predicted from a linear combination of minimum temperature and rainfall ($\log Y = 1.77 + [0.018 \times \text{rainfall}] + [0.029 \times \text{min temp}]$; $F = 4.01$; $P = 0.022$). There was no interaction between the *Ae camptorhynchus* population and maximum temperature ($P = 0.37$). In Hastings, the average number of *Ae camptorhynchus* adults caught/trap increased with the increase in the minimum temperature ($\log Y = 1.54 + [0.038 \times \text{min temp}]$, $F = 4.94$, $P = 0.031$), while the maximum temperature and rainfall did not have any significant effect on the number of *Ae camptorhynchus* adults trapped. In Tambo, the *Ae camptorhynchus* population showed positive linear relation with minimum temperature ($\log Y = 1.30 + [0.421 \times \text{Min temp}]$; $F = 7.02$; $P = 0.018$) and a nonlinear polynomial relationship with rainfall ($\log Y = 1.60 + 0.332X + 0.109X^2 + 0.004X^3$; $F = 5.07$; $P = 0.031$). In Rosedale, again, only the minimum temperature showed a linear interaction with the *Ae camptorhynchus* population ($\log Y = 1.59 + [0.042 \times \text{Min temp}]$; $F = 7.12$; $P = 0.021$) while the maximum temperature ($F = 0.81$; $P = 0.371$) and rainfall ($F = 0.162$; $P = 0.69$) did not have any significant effect on the number of *Ae camptorhynchus* adults trapped. In Bairnsdale, the *Ae camptorhynchus* population showed a positive linear interaction with minimum temperature ($\log Y = 0.109 + [0.073 \times \text{Min temp}]$; $F = 16.3$; $P = 0.0001$), while the population of other species (mostly of fresh water breeding species like *Cq linealis*, *Ae notoscriptus* and *Cx annulirostris*) showed a linear positive correlation with rainfall ($\log Y = 1.75 + [0.026 \times \text{rainfall}]$; $F = 4.55$; $P = 0.036$).

Discussion

At least 33 species of mosquitoes are known to occur in the southeast coast of Victoria (Russell 1993). In our survey, only 20 species of mosquitoes were recorded. Since the mosquito surveillance program concentrated only on trapping adults with CO_2-baited light traps, adults of uncommon species, like *Aedeomyia venustipes* (Skuse) and *Cx pseudomelanoconia* Theobald, could be missed. Further, the variations in the attractiveness of CO_2 to various mosquito species could have influenced the number of species trapped in these sites. Similar results were also reported by Russell *et al.* (1991) while using dry-ice baited EVS light traps for sampling mosquitoes, where several species of mosquitoes were rarely collected as adults, even though they were abundant as larvae. *Ae alternans* (Westwood) and *Ae vittiger* (Skuse), thought not

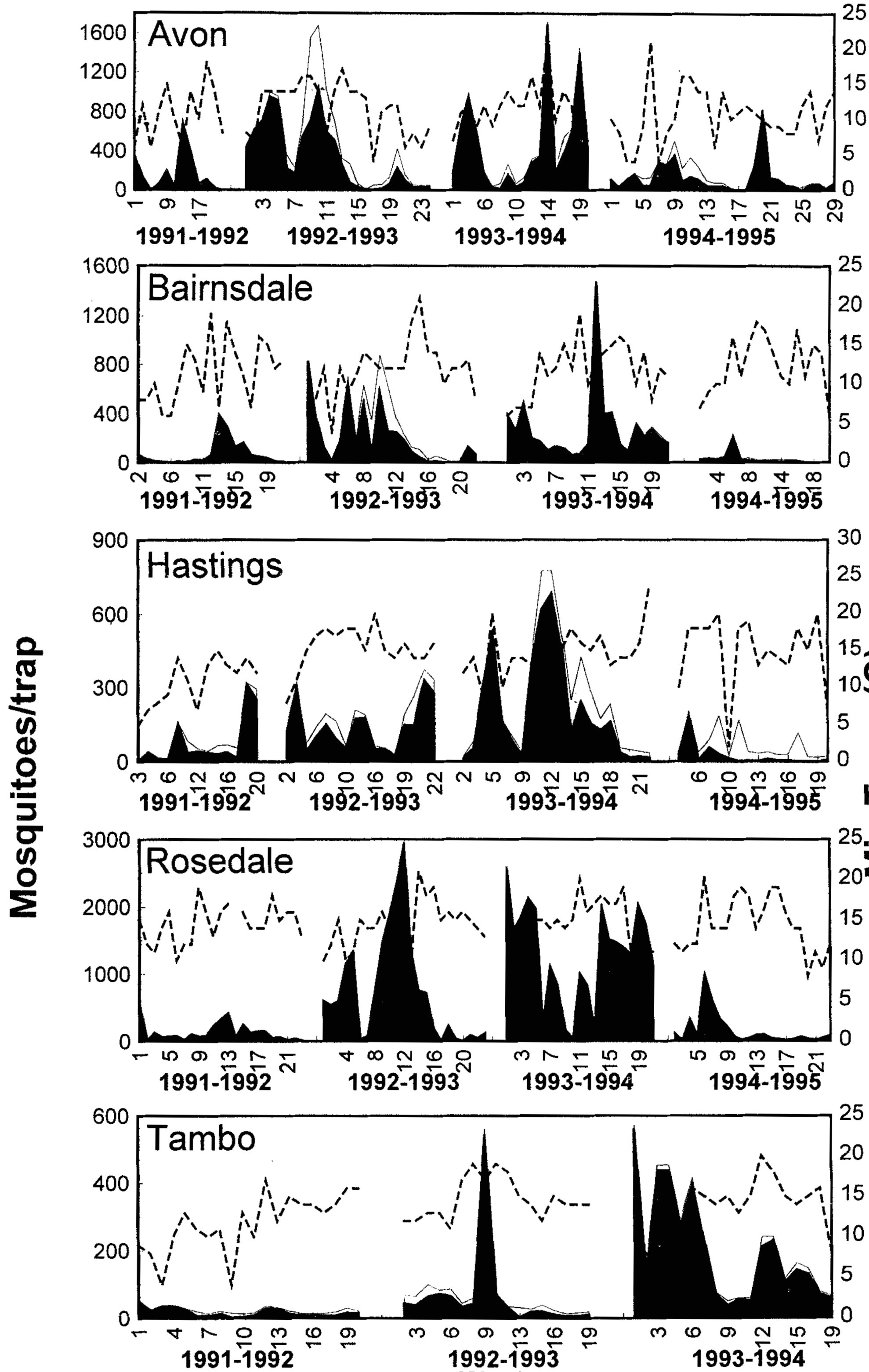

Fig. 3. Weekly population density fluctuations (mean number of mosquitoes/night in four EVS traps/shire/night) of *Ae camptorhynchus* (solid area) and other mosquitoes (unshaded area) plotted in the first Y-axis, in relation to minimum temperature plotted in the second Y-axis (dotted line) in five shires in the eastern coast of Victoria. For each season, the week numbers 1 to 29 represent the first week of November to the fourth week of April (weeks 1-4 = November, weeks 5-8 = December, weeks 9-13 = January, weeks 14-17 = February, weeks 18-21 = March and weeks 22-26 = April).

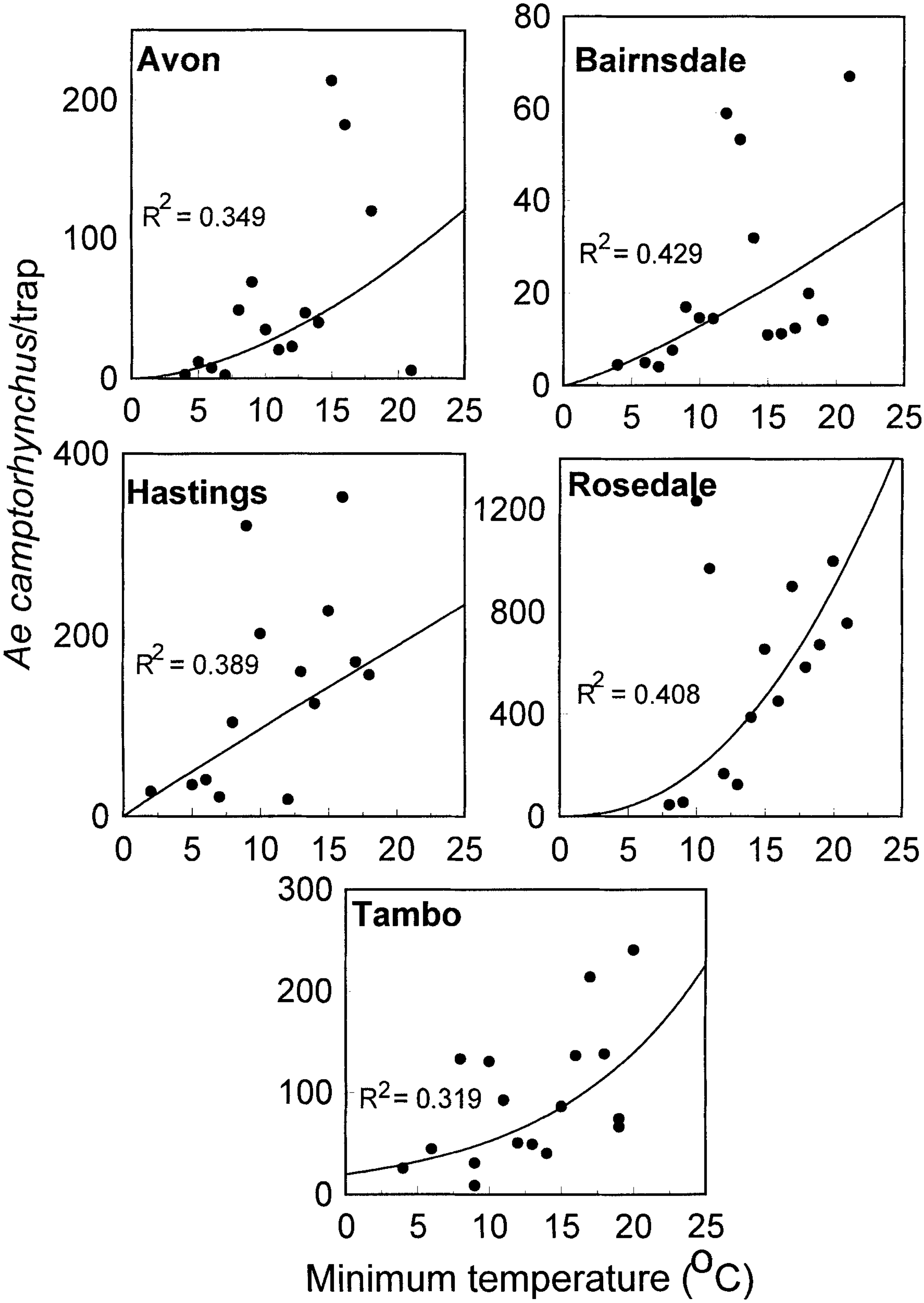

Fig. 4. Correlation between minimum temperature (°C) and *Ae camptorhynchus* abundance (adults/trap) in five shires in the eastern coast of Victoria.

to be present in the southeast coast of Victoria (Dobrotworsky 1965; Russell 1993), were recorded in three of the five coastal shires surveyed. Larvae of *Ae vittiger* were also collected from *Sarcocornia* swampland in the (Avon) eastern coastal region. Similarly, *Ae bancroftianus* Edwards which is not known to be present in the south of the dividing range in southeast Victoria (Dobrotworsky 1965; Russell 1993), was also recorded in Hastings. As other species like *Ae australis* (Erichson), *Ae dobrotworskyi* Marks, *Ae imperfectus* Dobrotworsky, *Ae rupestris* Dobrotworsky, *Cx fergusoni* (Taylor) and *Culiseta victorienis* (Dobrotworsky) which are known to present in southeast Victoria (Dobrotworsky 1965; Russell 1993) were not recorded, a detailed larval survey may be useful in ascertaining the species spectrum in these regions. Regular occurrence of *Cq linealis* and *Ae notoscriptus* (Skuse) in the collections indicates that fresh water breeding sites which are often influenced by the rainfall also occur around saltmarsh areas.

Ae camptorhynchus, the most prominent species in the southeast coastal region is active throughout the year. However, the *Ae camptorhynchus* population fluctuated widely, depending upon the average minimum temperature. The increased *Ae camptorhynchus* activity with the increase in the minimum temperature could possibly be due to either increased rate of development of immature mosquitoes resulting in higher mosquito abundance or increased activity (feeding and reproduction) of existing adults or both. Adult mosquito activity was very low when the average minimum temperature was below 5 °C. With the increase in the minimum temperature, the mosquito activity increased and reached its peak when the average minimum temperature reached 20 °C. However, survey of breeding sites during winter months in the eastern coastal region revealed that *Ae camptorhynchus* larvae remained active, even when the minimum temperature reached below 5 °C. There was no interaction between the average maximum temperature and *Ae camptorhynchus* population ($F = 0.083$, $P = 0.77$). Only in Avon and Bairnsdale, the rainfall was positively correlated with *Ae camptorhynchus* population while in Tambo the interaction between the rainfall and *Ae camptorhynchus* abundance was nonlinear. The lack of interaction between the rainfall and *Ae camptorhynchus* population in other shires suggests that tidal inundation could be the major factor in influencing the breeding site availability, thereby determining the mosquito abundance. Lindsay *et al.* (1989) also reported that the abundance of saltmarsh breeding species such as *Ae vigilax* (Skuse) and *Ae camptorhynchus* is associated with tidal inundation and rainfall on their saltmarsh breeding habitats in southwest Western Australia. Hence, it would be worthwhile to investigate the impact of daily tidal variations on the extent of flooding/inundation in future surveillance programs in the coastal region. However, the situation in the Gippsland region is different where the tidal variations influence the water level in the Gippsland lake system, which in turn influences the extent of inundation in various shires, depending upon the wind velocity and direction. Thus, the population of coastal saltmarsh breeding *Ae camptorhynchus*, as indicated by trap collections, depends mainly on the average minimum temperature, and to a lesser extent on the total weekly rainfall.

Ae camptorhynchus is implicated as the major vector of both RR and BF viruses in the southeast coast of Victoria (Mackenzie *et al.* 1994; Russell 1995). RR and BF viruses have been isolated from field collected *Ae camptorhynchus* and *Cq linealis* adults in the region (Campbell *et al.* 1989a, 1989b). RR virus has also been isolated from adults raised from field collected *Ae camptorhynchus* larvae (Dhileepan *et al.* 1996), indicating vertical transmission is one of the virus maintenance strategies in mosquito vectors. The potential role of *Ae camptorhynchus* as the major arboviral vector is further supported by the fact that more than 85% of adult mosquitoes trapped in the coastal Gippsland region were *Ae camptorhynchus*. However, there was no correlation between the *Ae camptorhynchus* population and RR disease incidence in humans in Gippsland region during 1992-93 and 1993-94 seasons (Dhileepan 1994). Russell (1988) also reported no correlation between *Ae camptorhynchus* population and RR disease incidence in humans in the southeast coast of New South Wales where *Ae vigilax* is the dominant species, and indicated that *Ae camptorhynchus* may not be the primary vector for RR. Thus, it would appear that *Ae camptorhynchus* may only be involved in the early season transmission and amplification of arboviruses in the coastal region of Victoria.

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