THE 1973 DENGUE HAEMORRHAGIC FEVER OUTBREAK IN SINGAPORE AND ITS CONTROL

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SYNOPSIS

The largest outbreak of dengue haemorrhagic fever in Singapore's history (1,187 cases, 27 deaths) is reported.

The outbreak began in April, peaked in August and was controlled by November. Concentrations of cases occurred in populated areas in the city and suburbs, coinciding with the distribution and density of the primary vector *Aedes aegypti*.

Highest morbidity rates (> 80 per 100,000 population) occurred in the young age groups, i.e. below 24 years, with morbidity rates falling with age. Highest fatality rates occurred in the 5–9 age group. More males than females (M/F = 1.46) were affected. Foreigners who had little or no immunity were affected most. One constituency (Serangoon Gardens) had a morbidity rate of 168.2 per 100,000 population while five others had morbidity rates ranging from 102 to 135 per 100,000 population.

The outbreak was successfully controlled by attacking the primary vector, using an integrated system involving vector source reduction, adult elimination by fogging, health education and law enforcement. Adult elimination was found to be the most effective and rapid method of terminating transmission.

The importance of disease notification, as well as routine disease and vector surveillances in forecasting outbreaks are discussed among other things.

INTRODUCTION

Dengue haemorrhagic fever (DHF) is among the 10 leading causes of hospitalisation and death in children in at least eight Asian countries in the tropics (WHO, 1975). It is endemic in many large Asian cities and spreads to smaller cities and towns during epidemics. In recent years, it has spread to the Pacific islands including Micronesia, Melanesia and Polynesia. There is every likelihood that it would

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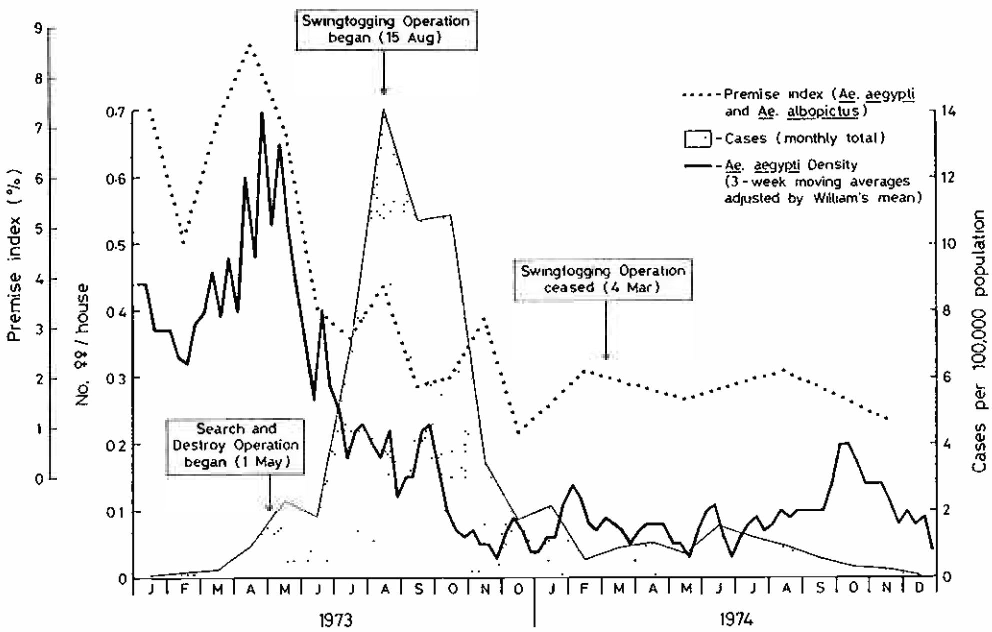

Fig. 1. Time distribution of DHF outbreak with vector control activities, *Aedes aegypti* density and *Aedes* premise index.

eventually encircle the whole globe and affect every country where the principal mosquito vector, *Aedes aegypti*, is found.

DHF* was first reported in Singapore in 1960 (Chew, et al, 1961). Since then, it has become endemic. In the first decade (1960-70) the largest epidemics occurred in 1966, 1967 and 1968 when respectively 630, 836 and 846 cases with 24, 21 and 18 deaths were recorded. In the second decade the largest epidemic occurred in 1973 when 1,324 cases with 27 deaths were reported (Goh & Chan, 1974). Although Goh & Chan (1974) reported 1,324 cases, careful checking of the records kept by the Epidemiology Unit, Ministry of the Environment, showed a total of 1,255 notified cases of which 44 were duplicated and 24 others were unaccountable. This gave an actual total of 1,187 notified cases.

This paper therefore describes the 1973 outbreak of 1,187 cases and its control.

DESCRIPTION OF OUTBREAK

The 1973 outbreak was first noted when the Microbiology Department, University of Singapore, reported to the Vector Control and Research Department on 21 April 1973 a sudden rise in the number of cases based on their routine serological diagnosis and confirmation of DHF cases from blood specimens submitted by hospitals. The outbreak was later confirmed when the incidence of DHF continued to increase and deaths were reported. The outbreak later proved to be the largest ever reported in the history of Singapore (Goh & Chan, 1974).

1. Time Distribution

DHF cases were reported throughout the year. A sharp increase was noted in April (Fig. 1). This continued to reach a peak in August when 308 cases were notified. After a fogging operation which began on 15 Aug 1973, a sudden decrease was seen in November and this tapered off to the original endemic level of less than 10 cases a week by the end of December.

2. Geographical Distribution

Cases were found throughout the country. Concentrations of cases occurred in urban and suburban housing areas with a wide scatter in the rural area (Fig. 2). The plotting of the cases was based on the patient's residential addresses in electoral constituencies and not on their places of work where infection could have also occurred since the vectors were day biters. In any case, it was impossible to determine exactly where each patient was infected. The human population figures were based on the 1973 population estimates obtained from the Department of Statistics.

The distribution of the disease coincided with that of the main vector *Aedes aegypti* (Fig. 3). Very high incidence (168.2 per 100,000 population) occurred in Serangoon Gardens (Fig. 4). Morbidity rates of 100-150 per 100,000 occurred in five con-

* Throughout this paper statistics on DHF in Singapore would include dengue fever as well.

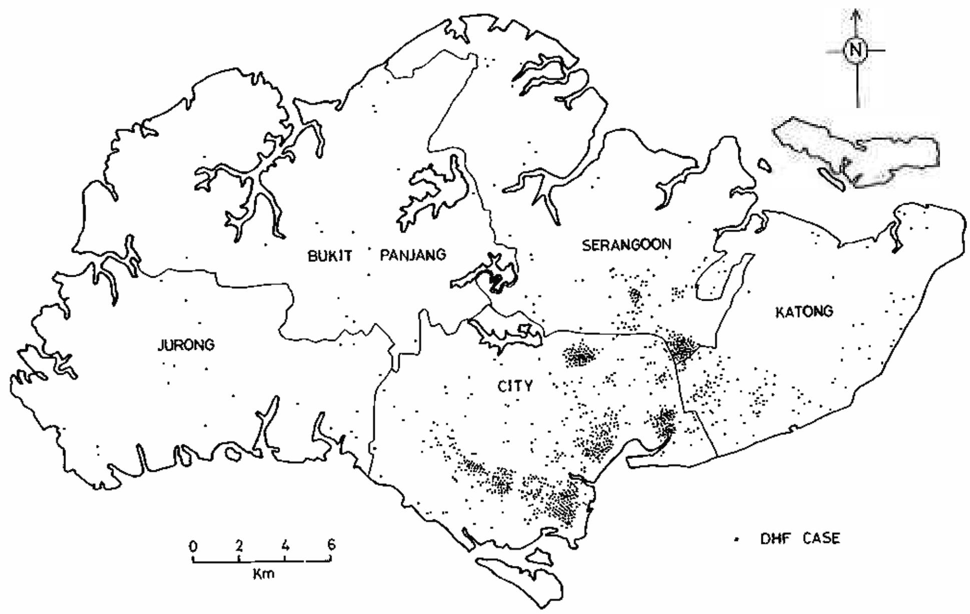

Fig. 2. Distribution of DHF, 1973.

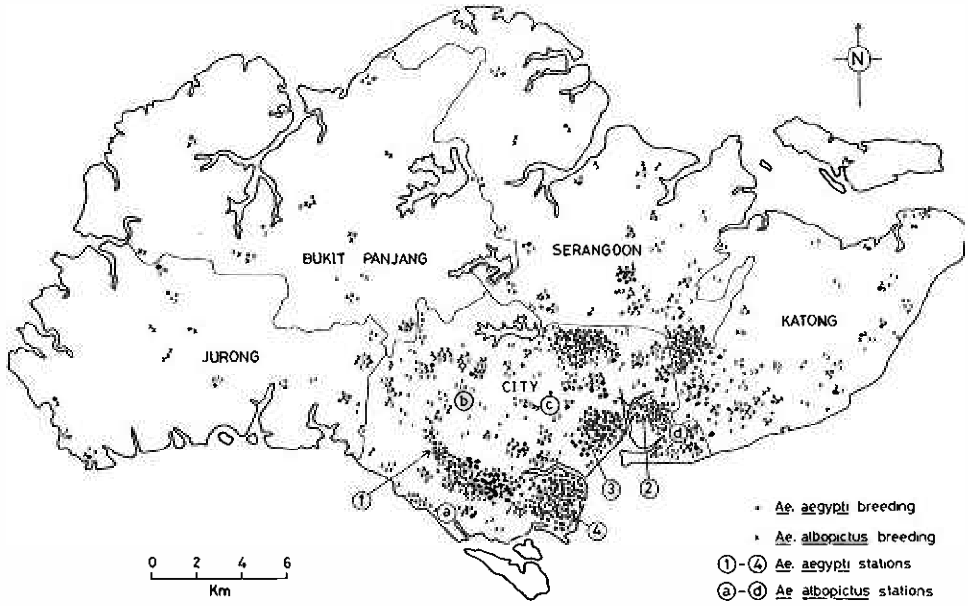

Fig. 3. Distribution of *Aedes* vectors, 1973.

stituencies (Paya Lebar, Mountbatten, Tanjong Pagar, Hong Lim and Rochor). Six constituencies had morbidity rates of 75-100 per 100,000 population, 19 had morbidity rates of 50-75 per 100,000 population while the rest (34) had morbidity rates of less than 50 per 100,000 population (Fig. 4).

3. Age Group Distribution

More than 75 per cent of the cases were below 24 years of age (Table I; Fig. 5). Maximum incidence (235 cases) was seen in the 10-14 age group. Highest morbidity rates (> 80 per 100,000 population) occurred in the age groups from 1 to 24, the highest (84.3 per 100,000 population) occurring in the 1-4 age group.

Highest fatality rate occurred in the 5-9 age group. More than 85 per cent of the fatal cases were below 14 years of age (Table II).

4. Sex Distribution

More males than females were affected (M/F = 1.46). The morbidity rates were roughly equal between the sexes in all age groups except the 15-19 and 20-24 age groups where the morbidity rates of males were significantly higher than those of the females (Table I).

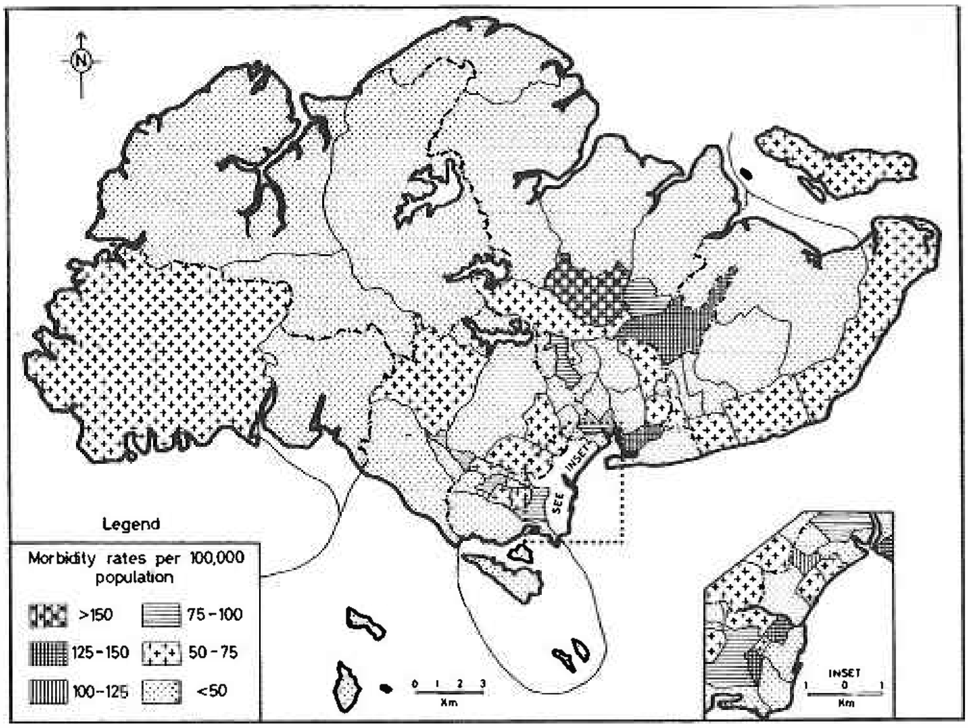

Fig. 4. Morbidity rates of DHF in electoral constituencies, 1973.

TABLE I—1973 DHF outbreak: Age and Sex Distribution and Morbidity Rate

Age Group (in years)	Mid-1973 Population† (thousands)			No. DHF Cases			Morbidity Rate per 100,000		
	Persons	Males	Females	Total	Males	Females	Total	Males	Females
< 1	49.8	25.8	24.0	27	15	12	54.2	58.1	50.0
1— 4	126.9	91.2	85.7	107	62	45	84.3	68.0	52.5
5— 9	261.0	133.5	127.5	218	110	108	83.5	82.4	84.7
10—14	287.2	147.9	139.3	235	131	104	81.8	88.6	74.7
15—19	275.3	141.0	134.3	225	148	77	81.7	105.0	57.3
20—24	230.5	117.7	112.8	194	140	54	84.2	119.0	47.9
25—29	164.4	82.8	81.6	86	45	41	52.3	54.4	50.3
30—34	142.6	71.0	71.6	38	19	19	26.7	26.7	26.5
35—39	120.8	61.2	59.6	24	11	13	19.9	18.0	21.8
40—44	108.8	57.3	51.5	9	6	3	8.3	10.5	5.8
45—49	89.6	48.2	41.4	6	3	3	6.7	6.2	7.3
50—54	76.2	40.8	35.4	6	3	3	7.9	7.4	8.5
55—59	64.8	33.5	31.3	0	0	0	0.0	0.0	0.0
60—64	57.2	29.3	27.9	0	0	0	0.0	0.0	0.0
65—69	37.6	18.3	19.3	2	2	0	5.3	10.9	0.0
70 & over	42.4	17.1	25.3	1	0	1	2.4	0.0	4.0
Unknown	—	—	—	9*	9*	0	—	—	—
Total	2185.1	1116.6	1068.5	1187	704	483	54.3	63.1	45.2

† Source: Department of Statistics, Singapore
* Including 7 soldiers probably in the 15-29 age group.

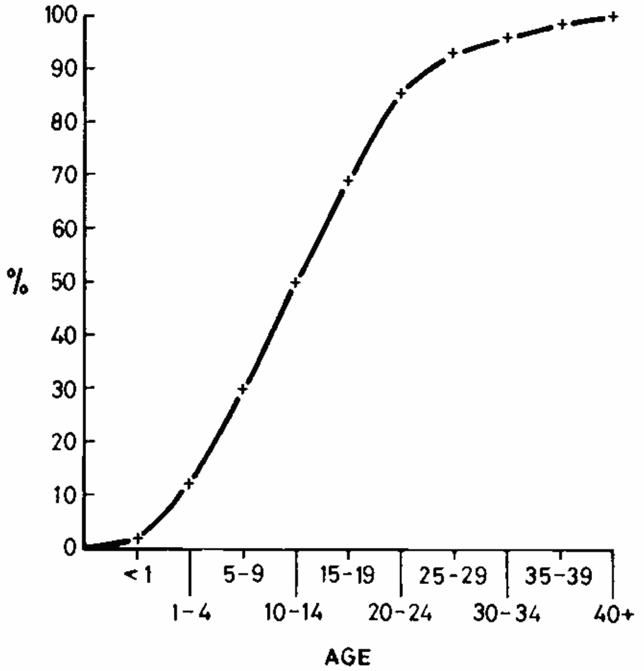

Fig. 5. Cumulative percentage distribution of DHF cases in the 1973 outbreak.

More males than females (M/F = 1.5) died from the disease (Table II).

5. Ethnic Group Distribution

The majority of cases (1,024 or 86.8 per cent) were Chinese (Table III). The remaining cases were Malays (5.2 per cent), Indians (5.0 per cent) and others (3.0 per cent). Seven cases (soldiers in the 15-29 age group) were of unknown ethnic group. The highest morbidity rate (85.6 per 100,000 population) occurred in 'others', a group consisting mainly of Japanese and European foreigners who obviously had little or no immunity against the disease since DHF does not occur in Japan or Europe. The local population in this group (i.e. 'others') comprising mainly Eurasians were not as greatly affected as were the foreigners.

TABLE II—1973 DHF outbreak: Age and Sex Distribution of Fatal Cases

Age Group (in years)	Total	Males	Females
< 1	1	1	0
1—4	6	2	4
5—9	11	4	7
10—14	5	5	0
15—19	2	2	0
20—24	1	1	0
25—29	0	0	0
30—34	1	0	1
Total	27	15	12

CONTROL OF THE 1973 OUTBREAK

An ad hoc Committee for the control of the epidemic was immediately formed on notification of the outbreak, with the Head of the Vector Control & Research Department as Chairman. Action was immediately taken to break the chain of disease transmission by attacking the vectors. The trend of the disease was followed from cases notified to the Epidemiology Unit and from the number of estimated cases notified by the Microbiology Department.

On 1 May 1973, a "Search & Destroy" operation was launched to search and destroy major sources of *Aedes* breeding. Attention was focussed on some 400 construction sites where *Aedes* breeding and harbourage were found to be profuse. The construction sites were fogged with 0.2 per cent bioresmethrin from Reslin 10/10 (a com-

TABLE III—1973 DHF outbreak: Ethnic Group Distribution of Cases

Ethnic group	Mid-1973 Population*		DHF Cases		Morbidity Rate per 100,000
	Persons	%	No.	%	
Chinese	1,663,400	76.1	1,024	86.8	61.6
Malays	329,100	15.1	62	5.2	18.8
Indians	151,700	6.9	59	5.0	38.9
Others	40,900	1.9	35	3.0	85.6
Total	2,185,100	100.0	1,187‡	100.0	54.3

* Source: Department of Statistics, Singapore
‡ Including 7 cases of unknown ethnic group

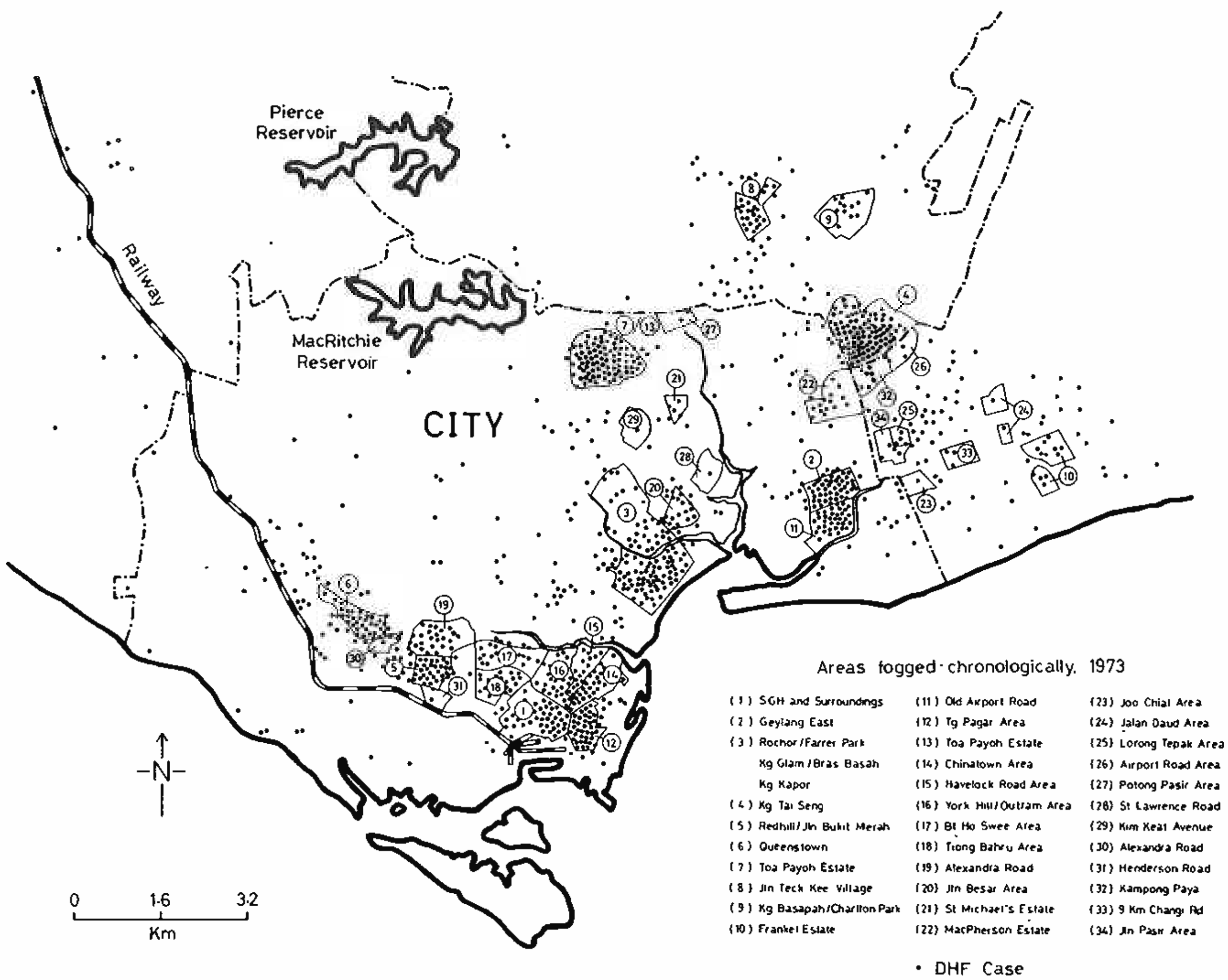

Fig. 6. Areas fogged chronologically in 1973 to control the 1973 DHF outbreak.

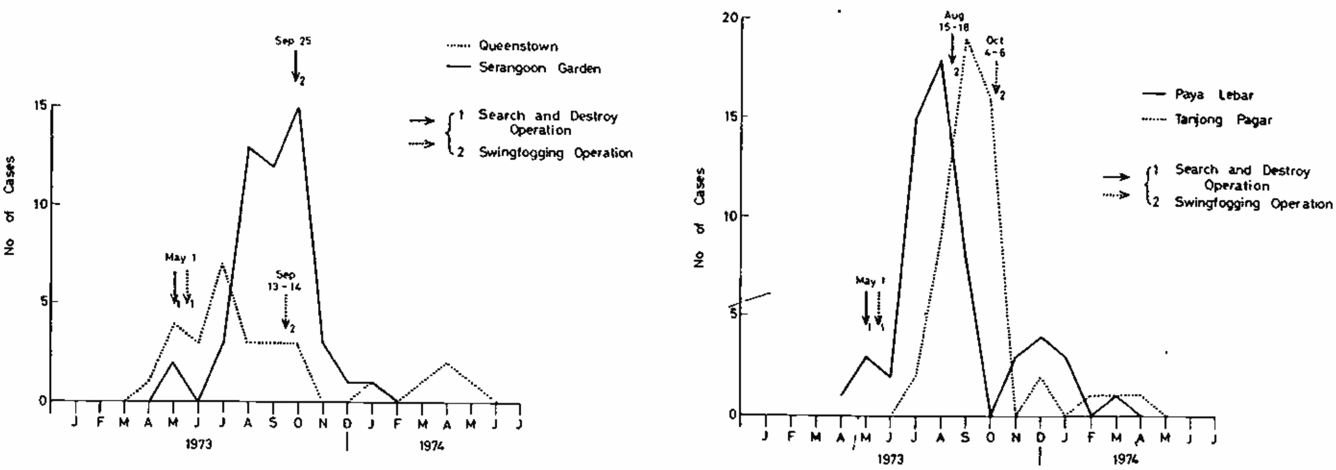

Fig. 7. Effect of *Aedes* control on DHF incidence in 4 constituencies, Singapore, 1973-1974.

mercial product containing 10 per cent of the active ingredient bioresmethrin and 10 per cent of the synergist piperonyl butoxide) to kill the adult vectors and treated with 1 per cent Abate sand granules or 1 per cent malathion emulsion to kill the immature stages. However, despite these measures, more DHF cases were reported. It was subsequently found that the dominant species in construction sites was *Ae. albopictus* and not *Ae. aegypti* which accounted for only 20 per cent of total *Aedes* breeding in construction sites. Thus, on 15 Aug 73, an intensified integrated *Aedes* control programme was carried out. This involved:

(a) Elimination by indoor fogging of the main

TABLE IV—Logistics involved in "swingfogging operation" to control DHF outbreak, 1973.

Month	No. of areas fogged (see map)	No. of premises fogged	*Manpower			Chemicals (litres)				Cost ($)		
			No. men used	No. hours spent	No. man-hours	Reslin	Kerosene	Diesolene	Petrol	Manpower	Chemicals	Total
1973 Aug	4	11170	89	103	2017	45.83†	2266.91	0	386.33	3360.19	2846.59	6206.78
Sep	7	37837	395	87	4947	143.74	6952.47	0	1433.86	6845.06	8979.77	15824.83
Oct	5	21781	200	60	2400	62.73	2765.22	0	824.03	3948.60	3943.90	7892.50
Nov	6	30485	224	96	3588	90.25	4518.00	0	1540.00	6475.99	5887.22	12363.21
Dec	12	3868	305	56	1392	25.14	530.00	820.0	426.50	2351.70	1586.32	3938.02
Total	34	105141	1213	402	14344	367.69	17032.60	820.0	4610.72	22981.54	23243.80	46225.34
1974 Jan	10	4499	277	48	1228	18.75	799.40	145.6	247.32	2049.76	1184.85	3234.61
Feb	10	4268	270	48	1336	24.48	891.26	382.2	364.00	2360.04	1548.57	3908.61
Mar	1	99	17	4	68	1.08	0	54.6	9.10	115.10	62.07	177.17
Total	21	8866	564	100	2632	44.31	1690.66	582.4	620.42	4524.90	2795.49	7320.39
G. Total	55	114007	1777	502	16976	412.00	18723.26	1402.4	5231.14	27506.44	26039.29	53545.73

Cost of fogging 1 premise or house—$0.47

* Cumulative from individual operations.

† Not including 6.77 litres of neopybuthrin at $34.75/litre

Cost of Reslin = $51.00/litre
Cost of Kerosene = $0.165/litre
Cost of Diesolene = $0.0697/litre
Cost of Petrol = $0.35/litre

TABLE V—Source reduction through "Search and Destroy" operation to control DHF outbreak, 1973-1974

Survey Period		No. of residences@		No. of construction @ sites		Premise Index (%)		No. Orders served		No. Summonses served	
		Examined	Breeding	Examined	Breeding	Residences	Constr. sites	Residences	Constr. sites	Residences	Constr. sites
1973											
Apr	27-30	2931	268	124	66	9.14	53.23	117	2	2	13
May	1-31	17164	995	1046	213	5.80	20.36	870	125	17	129
Jun	1-30	17015	578	796	145	3.40	18.22	610	34	53	92
Jul	1-31	15605	467	939	83	2.99	8.84	436	46	17	74
Aug	1-31	11335	455	918	111	4.01	12.09	315	39	15	82
Sep	1-30	25973	581	815	111	2.24	13.62	495	43	13	67
Oct	1-31	22797	451	815	88	1.98	10.80	472	40	17	64
Nov	1-30	14828	410	840	86	2.77	10.24	410	19	15	74
Dec	1-31	26604	277	924	82	1.04	8.87	250	30	14	57
Total		154252	4482	7217	985	2.91	13.65	3975	378	163	652
1974											
Jan	1-31	15205	244	903	63	1.60	6.98	242	13	2	51
Feb	1-28	14407	286	1042	91	1.99	8.73	314	38	16	51
Mar	1-31	17384	244	1135	100	1.40	8.81	274	48	18	78
Apr	1-30	21859	456	1074	65	2.09	6.05	435	34	27	58
May	1-31	17452	386	978	87	2.21	8.90	369	37	26	74
Jun	1-30	19905	402	1133	53	2.02	4.68	305	15	21	48
Jul	1-31	25034	355	1111	72	1.42	6.48	322	46	26	57
Aug	1-31	20589	480	1124	56	2.33	4.98	348	37	35	51
Sep	1-30	15894	367	901	53	2.31	5.88	310	16	35	46
Oct	1-31	17017	440	900	67	2.59	7.44	367	22	23	64
Nov	1-30	14823	356	696	61	2.40	8.76	312	35	18	68
Dec	1-31	13237	336	565	35	2.54	6.19	258	22	26	29
Total		212806	4352	11562	803	2.04	6.95	3856	363	273	675
Grand Total		367058	8834	18779	1788	2.41	9.52	7831	741	436	1327

@Include repeats in high endemic areas.

vector *Ae. aegypti* in high endemic areas and areas with high *aegypti* breeding;
(b) Source reduction;
(c) Health education; and
(d) Law enforcement.

Elimination of adult *Ae. aegypti* through large scale fogging of all premises in high endemic areas (Fig. 6) began on 15 Aug 73 and was not lifted until 4 Mar 74 when the disease was under control (Fig. 1). By the end of 1973, a total of 105,141 premises were fogged, and by the end of March 1974, a further 8,866 premises were fogged (Table IV). The fogging operation involved the use of 20 swingfog machines (model SN 11), and the deployment of 7 to 73 men at each fogging site, the number varying according to the size of the area and the availability of vector control personnel.

Source reduction which began in April 1973, intensified in May 1973, was later synchronized with the fogging operation. By the end of 1973, a total of 154,252 residential premises and 7,217 construction sites were checked including repeats in high endemic areas (Table V). By the end of 1974 a further 212,806 residential premises and 11,562 construction sites were inspected for larval breeding.

Health education was carried out together with source reduction right from the beginning in April 1973. The outbreak was covered widely on radio, television and newspapers. A TV documentary to educate the public on simple preventive and control measures for *Aedes* breeding in the home was released on 17 Sep 73. This was augmented by the distribution of 120,000 pamphlets in various languages especially in high endemic areas. Householders were motivated through personal contact by vector control personnel to keep their premises free of *Aedes* breeding. This was reinforced by increased and sustained law enforcement action.

Law enforcement was stepped up in April 1973 when serious efforts were made to control the outbreak. It was sustained right through 1973 and 1974. By the end of 1973, a total of 3,975 orders and 163 summonses under the Destruction of Disease Bearing Insects Act were served on householders found breeding mosquitoes and 378 orders and 652 summonses were served on developers and contractors whose construction sites were found breeding mosquitoes on two or more occasions (Table V). By the end of 1974, a further 3,856 orders and 273 summonses were served on householders and 363 orders and 657 summonses were served on developers and contractors (Table V).

As a result of all the intensive integrated control measures, the fortnightly *Aedes* premise index dropped from 9.1 per cent in April 1973 to 5 per cent by the end of May 1973, three weeks after the mounting of the "Search and Destroy" operation on 1 May 73. After May 1973, the fortnightly premise index fluctuated between 4 per cent and 1 per cent with an average of 2.4 per cent. This level was maintained right through 1973 as well as 1974 (Fig. 1). The *Ae. aegypti* density also fell from a peak of 0.7 ♀♀ /house in April 1973 to less than 0.2 ♀♀ /house by early October 1973, fluctuating around this level for the rest of 1973 and right through 1974 (Fig. 1).

The number of reported DHF cases dropped dramatically in November 1973 following the swingfogging operation launched on 15 Aug 1973 (Fig. 1). The dramatic drop occurred only after 22 of the most highly endemic areas were fogged (Fig. 6). Although a total of 55 areas were fogged, the number of premises fogged (101,273) in the 22 areas by the end of November 1973 represented 88.8 per cent of the total premises fogged (Table IV). The incidence of DHF dropped from an all-time high of 308 cases or 14.1 per 100,000 population in August 1973 to 38 cases or 1.7 per 100,000 population in December 1973 and to 10 cases or 0.46 per 100,000 population in February 1974, and remained at about this level for the rest of 1974 (Fig. 1). Dramatic decreases in incidence of reported DHF cases were noted following fogging in almost all constituencies in which highly endemic localised areas were fogged. Four such constituencies are illustrated (Fig. 7).

Thus, the multi-pronged, integrated *Aedes* control measures were effective in containing the outbreak.

DISCUSSION

In the last decade, Singapore saw two large outbreaks of DHF, one in the years 1966-8, and the other in 1973. It is not known whether these were due to increases in the vector density or to host susceptibility or to virulence of the virus strain or strains then circulating in the population or to a combination of these or other factors. However, in these epidemic years, the combined *Aedes* premise index had exceeded 5 per cent (Fig. 8). In the non-epidemic years during the decade, the combined *Aedes* premise index had remained generally below 5 per cent as a result of inten-

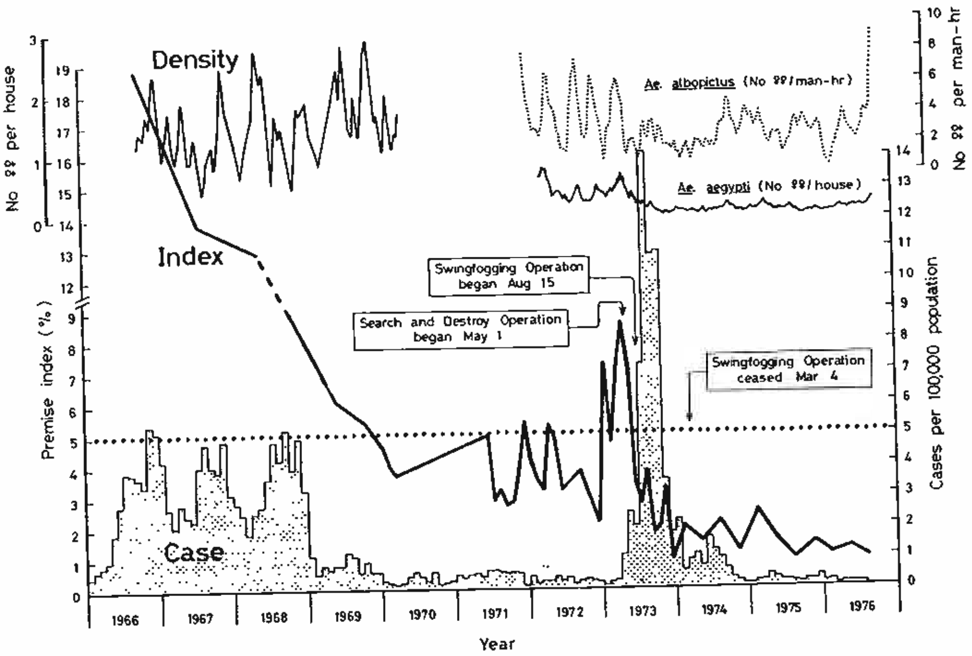

Fig. 8. DHF incidence, *Aedes* vector density and premise index in Singapore in the last decade.

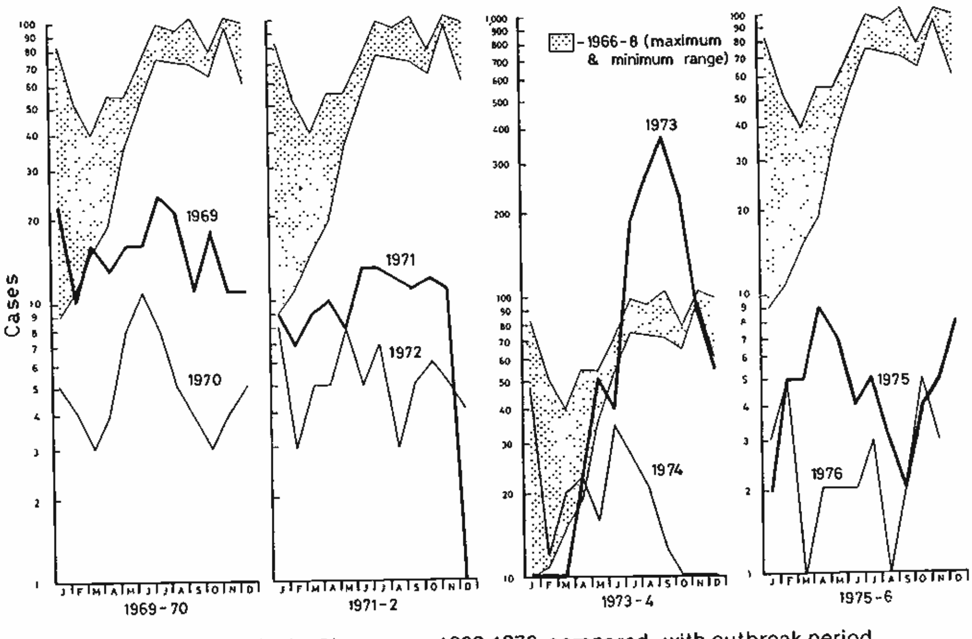

Fig. 9. Incidence of DHF in Singapore, 1969-1976 compared with outbreak period 1966-1968.

sified vector control measures (Fig. 8; Chan, 1976). It is therefore the experience of Singapore that when the combined *Aedes* premise index exceeds the 5 per cent level, the vector density would be at a level high enough to cause outbreaks. Apparently there is a minimum vector density (the threshold density) which would support transmission of DHF at epidemic levels. The current practice is therefore to routinely control all areas with more than 5 per cent premise index to below this level in order to prevent DHF outbreaks.

In the 1966-8 outbreaks, there were two peaks in the year, one (the smaller) in August and the other (the larger) in November (Chan, Ho & Chan, 1971). In the 1973 outbreak, the second or November peak was not observed. This shows that the integrated control measures had been effective in controlling the disease.

The disease had consistently shown a higher incidence every second year since 1969 (Fig. 9) as was the case in Thailand during the period 1958-

TABLE VI — 1973 DHF outbreak: Number of cases estimated by Department of Microbiology, University of Singapore, based on serology

Month	Specimens received	Specimens Examined			No. of Specimens not examined (z)	Estimated* no. of DHF Cases
		Negative (x)	Positive			
			Paired sera (y)	Single sera		
Jan	44	6	9	4	25	28
Feb	18	4	3	5	6	11
Mar	23	2	7	3	11	18
Apr	58	9	16	15	18	42
May	209	29	41	25	114	133
Jun	251	37	35	37	142	141
Jul	421	21	27	117	256	287
Aug	388	31	55	115	187	289
Sep	352	42	49	99	162	235
Oct	251	38	57	39	117	166
Nov	128	32	34	14	48	73
Dec	104	20	20	8	56	56
Total	2247	271	353	481	1142	1479

* Estimate assumes $\left(\frac{y}{x+y}\right)$ of (z) would have been positive for DHF if tests were completed.

Example:

For January, total positive specimens examined = 9 + 4 or 13.

If the 25 specimens not examined were examined, then the number of positive specimens would be $\frac{y}{x+y}$ xz or $\frac{9}{6+9} \times 25 = 15$.

∴ Total positive = 13 + 15 = 28.

1968 (WHO, 1970). The significance of this is not really known but is likely related to the immunological status of the population.

Routine disease and vector surveillances are important in predicting outbreaks and therefore in enabling control measures to be taken early. Any sudden and significant increase in both the disease incidence and vector density would be indicative of a possible outbreak. In the 1973 outbreak, it was the routine surveillance of clinical cases by the Microbiology Department, University of Singapore, which had enabled the outbreak to be recognized early.

Routine vector surveillance by the Vector Control & Research Department could have also predicted the outbreak, in fact even earlier, since an increase in vector population normally precedes an increase in the disease incidence. As early as January 1973, a two-fold increase in the *Aedes* premise index (from below 5 per cent during the period November 1969 to December 1972 to 11.2 per cent in January 1973) was already noted (Chan, 1976). But unfortunately, the significance of this increase above the 5 per cent level was not known then and could not be used to forecast and forewarn the impending outbreak. The present practice therefore is to routinely use both the disease incidence and vector density (e.g. premise index and adult female density) as indicators for predicting DHF outbreaks.

For effective DHF control, it is important that the trend of the disease is followed consistently and continuously, especially just before, during and after an outbreak. Otherwise it would not be possible to evaluate whether vector control measures implemented had been effective. In the 1973 outbreak, the trend of the disease was followed from serological diagnosis and confirmation of DHF cases by the HI (haemagglutination-inhibition) and the CF (complement-fixation) tests carried out by the Microbiology Department, University of Singapore. These methods were unfortunately too slow to be of much practical value. With the recent development of newer laboratory techniques such as counterimmunoelectrophoresis (Churdboonchart et al, 1974), the intra-thoracic inoculation of mosquitoes (Rosen & Gubler, 1974), and the staphylococcal agglutination-inhibition test (Chan, Teoh & Aw, 1975), the hope for rapid methods of diagnosis suitable for routine use in providing on-the-spot reliable statistics on the disease as well as in assisting clinicians, becomes brighter.

There is a need to make DHF legally notifiable* in Singapore in order to have reliable statistics on the disease. Prior to 1973, meaningful statistics on DHF were available only from the Microbiology Department, University of Singapore, which had since the 1960 outbreak routinely examined and confirmed by serology, blood specimens voluntarily submitted by clinicians from four city general hospitals (Chan, Ho & Chan, 1971). The Microbiology Department had consistently estimated the number of DHF cases, by extrapolation, from the percentage of blood sera found positive for dengue as illustrated in Table VI and was able to project a true epidemic pattern of the disease (Chan et al, 1971). Although DHF was made notifiable administratively by the Ministry of Health with effect from 18 Oct 1966, many government and private doctors could not really provide notification prior to 1973 because of the lack of proper technical guides for its clinical diagnosis, DHF being then a relatively new disease. As a result, DHF was under-reported prior to 1973. Furthermore, a good percentage of the DHF cases notified had probably included other diseases with similar clinical symptoms. Thus, reliable statistics on the disease were not available. However, the seriousness of the 1973 outbreak had prompted the Epidemiology Unit, then newly formed under the Ministry of the Environment, to arrange for another administrative notification on a firmer basis in September and October 1973. This had resulted in subsequent regular notifications of DHF to the Epidemiology Unit from all government hospitals and clinics and from the University and armed forces. Notification of DHF was further augmented recently by the publication of technical guides for its diagnosis, treatment, surveillance, prevention and control by WHO (WHO, 1975).

From the experience gained in the control of the 1973 outbreak, it has become quite clear that selective control of the primary vector *Ae. aegypti* in all high endemic areas where this vector is normally also prevalent, could stop the outbreak quickly if the control were thorough, intensive and carried out over a short period of time. The extermination of virus-harbouring vector females through fogging and the prevention and suppression of vector breeding through continuous and systematic source reduction, health education and legislation, had proven to be highly effective in controlling the disease. The choice of bioresmethrin as the adulticide had shown the wisdom of using this safe and rather odourless insecticide with low mammalian toxicity as no refusal of fogging by the public nor accidental poisoning of humans and domestic animals were encountered. The use of the hand-portable swingfog machine (model SN 11) had shown that it is effective and suitable for *Aedes* control in highrise buildings. Aerial ULV spraying and a heavy ground machine such as the LECO ULV which is suitable for fogging premises up to two storeys high, are unsuitable for use in the Singapore context where highrise buildings predominate.

Singapore has developed a highly successful integrated programme of *Aedes* control which could both speedily control and prevent outbreaks (Chan, 1976). WHO in its 25th Regional Committee Meeting has hailed this programme as "the most highly developed . . . which can serve as a model for other countries" (WHO, 1974). Much of Singapore's success had been due to the proper utilization of vector bionomics and ecology for vector surveillance and control (Chan, 1973). Other elements and factors contributing towards the success of DHF control in Singapore include:—

(a) a good routine disease surveillance and notification system;
(b) a good routine vector surveillance and control system;
(c) an effective strategy for the emergency control of DHF outbreaks and
(d) an effective organization and administration accustomed to planning and carrying out vector control operations within hours from notification of DHF outbreaks.

*This has been done recently. DHF was included among other infectious diseases for notification by law in the Infectious Diseases Act, 1976, under "The Infectious Diseases (Delegation of Powers) Notification" gazetted on 15 July 1977 and scheduled for commencement on 1 August 1977.

The effectiveness of Singapore's integrated control programme was borne out recently (1976) when Singapore was spared an outbreak which swept through the region, affecting several neighbouring countries.

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REFERENCES

1. Chan, K. L.: Ecological approach to integrated control of *Aedes aegypti* and *Aedes albopictus* in Singapore. Proc. 2nd Congress. J. Sing. Nat. Acad. Sci., 3, 116-129, 1973.
2. Chan, K. L.: The control of dengue haemorrhagic fever in Singapore with special reference to the 1973 outbreak. Proc. Nanyang University Institute of Natural Sciences, Symposium on Our Environment, October 1976 (in print).
3. Chan, Y. C., B. C. Ho & K. L. Chan: *Aedes aegypti* (L.) and *Aedes albopictus* (Skuse) in Singapore City. 5. Observations in relation to dengue haemorrhagic fever. Bull. Wld. Hlth. Org., 44, 651-658, 1971.
4. Chan, Y. C., Teoh, S. H. & Aw, S. E.: Staphylococcal agglutination-inhibition reaction: a rapid and simple test for dengue antibodies. Sing. Med. J., 16(3), 194-195, 1975.
5. Chew, A., Ho, Y., Lee, Y. K., Gwee, A. L., Khoo, O. T., Lim, C. H. and Wells, R.: A haemorrhagic fever in Singapore. Lancet, 1, 307-310, 1965.
6. Goh, E. H., & Chan, K. L.: The 1973 dengue haemorrhagic fever outbreak in Singapore. Sing. Publ. Hlth. Bull., 14, 24-29, 1974.
7. Rosen, L. & Gubler, D.: The use of mosquitoes to detect and propagate dengue viruses. Am. J. Trop. Med. Hyg., 23, 1153-1160, 1974.
8. Churdboonchart, V., Harisdangkul, V. & Bhamarapravati, N.: Countercurrent immunoelectrophoresis for rapid diagnosis of dengue haemorrhagic fever. Lancet, 2, 841, 1974.
9. WHO: Dengue haemorrhagic fever in Thailand. WHO Wkly Epidem. Rec., 18, 201-204, 1970.
10. WHO: Report of the technical discussions on 'Control of vector mosquitoes of dengue haemorrhagic fever'. WHO Regional Committee Meeting. 25th Session, Kuala Lumpur, Malaysia, 2-10 September 1974, WPR/RC25/TD8.
11. WHO: Technical guides for diagnosis, treatment, surveillance, prevention and control of dengue haemorrhagic fever. WHO, Geneva, 1975.