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THE GLOBAL SOCIO-ECONOMIC IMPACT OF TROPICAL CYCLONES

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ABSTRACT

On the basis of recent and historical evidence the regions of the world most vulnerable to the effects of tropical cyclones are identified. These regions comprise the densely populated delta regions, the isolated island groups, and the highly developed industrialised and residential coastal zones in higher latitudes. The death toll due to tropical cyclones is shown to exceed that of other major natural hazards and the annual damage bill is estimated to exceed $A6000 million. On the basis of information provided by many meteorological services, the tracks of future tropical cyclones of super-intensity that are likely to be catastrophic in their socio-economic impact are postulated.

INTRODUCTION

At an international symposium on 'The Impact of Tropical Cyclones on Oil and Mineral Development in Northwest Australia' in Perth in November 1974, a parallel was drawn between the recently adopted slogan for the State of Western Australia as a 'State of Excitement' and the state of excitement in which the earth's atmosphere and oceans continually find themselves in balancing the heat and momentum budgets of the planet, and in which the development, life cycle and degeneration of tropical cyclones play a major role.

Since that occasion in 1974 Australia, along with other countries in Oceania, Asia and the West Pacific, the Caribbean and the United States of America, has been buffeted by catastrophic cyclones, of which cyclone Tracy (which devastated Darwin on Christmas Day 1974) is the example closest to home. The Andhra Pradesh Province in India (20 000 lives lost during the destruction of 47 villages and colossal crop destruction), Sri Lanka (1000 lives lost with major economic loss), the Caribbean (3000 lives lost in the Dominican Republic during hurricane David), a direct hit by typhoon Rita on Manila (nearly 500 dead), hurricane Meli in Fiji (50 lives lost) are examples that indicate the geographical distribution of destruction. In the southwest of Western Australia cyclones Alby and Hazel have shaken citizens believing themselves to be immune from cyclone dangers.

The immediate and long-term impact of tropical cyclones is dependent on the mode of life and economies of affected countries, the frequency and magnitude of storms, and the willingness, capacity and understanding of the dangers involved by communities at risk. The measurement of past events and the prediction of the future impact of hazards is part of the ongoing science of human geography that studies the evolving struggle of communities to adapt to changing environmental conditions, natural resources, social systems and cultural attitudes. Regional variations in the socio-economic impact of tropical cyclones are related to the geographic vulnerability of communities, their experience of severe storms, population density, coastal and inland topography, land usage, industrialisation, social organisation, isolation, and so on. This summary draws on the experience of history to predict the potential for the future impact of these storms.

RELATION TO OTHER NATURAL HAZARDS

The impact of tropical cyclones may be placed in perspective with other natural hazards. Table 1 lists the natural disasters, excluding drought and bushfires, which have claimed 10 or more lives chronicled in the annual year books of *Encyclopedia Brittanica* for the 15-year period 1964 to 1978. This source does not provide representative information concerning disasters in the USSR or mainland China. It is noted that 93 tropical cyclone occurrences of the 484 disasters listed were responsible for about 60 per cent of all lives lost. Earthquakes were the second largest killer. Riverine and flash floods, often associated with tropical cyclones, represented the most frequent hazard. During this period the Philippines, Bangladesh and Japan suffered the most fatalities from severe tropical cyclones (Table 2).

Table 1 Natural disasters chronicled in the annual year books of *Encyclopaedia Brittanica* (1964-78). Droughts and bushfires are excluded.

Disaster	Occurrences	Deaths	Greatest
Tropical Cyclones	93	416 972*	300 000§ (Bangladesh 1970)
Non-Tropical Cyclone Storms	41	1860	166 (USA 1966)
Tornadoes, Severe Local Storms	44	4062	540 (Bangladesh 1969)
Heavy Rain - Floods	160	26 724	8 000§ (South Vietnam 1964)
Avalanches, Landslides	56	5790	1450 (Peru 1974)
Heat-Cold Waves	5	505	291 (India 1973)
Earthquakes - Tidal Waves	79	195 328†	66 794 (Peru 1969)
Volcanic Eruptions	6	2572	2000§ (Zaire 1973)
Total	484	653 813	

* including 402 000 based on estimates

† including 111 000 based on estimates

§ estimate

Table 2 Countries that experienced severe tropical cyclones for the years 1964 to 1978. The data relate only to cyclones in which a minimum of ten deaths were reported. (Source *Encyclopaedia Brittanica*).

Country	Occurrences	Deaths
Philippines	16	3560
Bangladesh	15	359 725*
Japan	15	1507
Taiwan	8	506
USA	7	747
India	5	41 308*
Mexico	4	705
Caribbean Is.	4	529
Hong Kong	4	164
Honduras	2	5051*
Sri Lanka	2	1850*
Sth Vietnam	2	149
Australia	2	82
Mozambique	1	1000*
Oman	1	100
Burma	1	100
Samoa	1	90
Malagasy	1	31
Fiji	1	25
Guadeloupe	1	13
Totals	93	416 972

* includes estimates

HISTORICAL CATASTROPHES

It is useful to place the preceding 15-year sample in context with the great catastrophes in history in which 100 000 or more deaths were caused by tropical cyclones and cyclonic floods (Table 3). If the history of the last century is repeated it is not unreasonable to expect that the potential exists for a repetition of such catastrophes on the Asian mainland. The magnitude of the impact will reflect progress in mitigation and community preparedness in the years ahead.

Table 3 Tropical cyclone and flood catastrophes of historical importance (from various sources).

Years	City/Country	Cyclone	Flood
1281	Kyushu	100 000	
1642	Kaifong		300 000
1737	Calcutta	300 000	
1851-66	Yangtze River		40-50 million
1876	Chittagong	300 000	
1881	Haiphong	300 000	
1882	Bombay	100 000	
1887	Yangtze River		1.5 million
1911	Yangtze River		100 000
1915	Canton		100 000
1931	Hwan-Po		millions
1931	Yangtze River		140 000
1939	China		200 000
1970	Bangladesh	300 000	
1971	Nth Vietnam		100 000

MAJOR CATEGORIES OF ECONOMIC DAMAGE

The most frequent types of potential damage accompanying tropical cyclones is shown in Fig. 1. The category of damage is highly dependent upon the particular geographic vulnerability and economy and mode of life of the affected community, as well as the dynamic characteristics of the storm as it makes landfall and moves inland.

GLOBAL OCCURRENCE

About 80 to 100 tropical cyclones occur each year, some two-thirds of them in the northern hemisphere. While most cyclones originate between about 8^{o} and 25^{o} latitude their tracks may extend beyond 35^{o} or 40^{o} latitude. If it is accepted that a typical cyclone immediately affects an area about $1^{o} \times 1^{o}$ in dimension, corresponding to about 100 km length of coastline, there are about 800 such separate prime target areas continuously on offer for the impact of tropical cyclones. Within each such section, substantial local

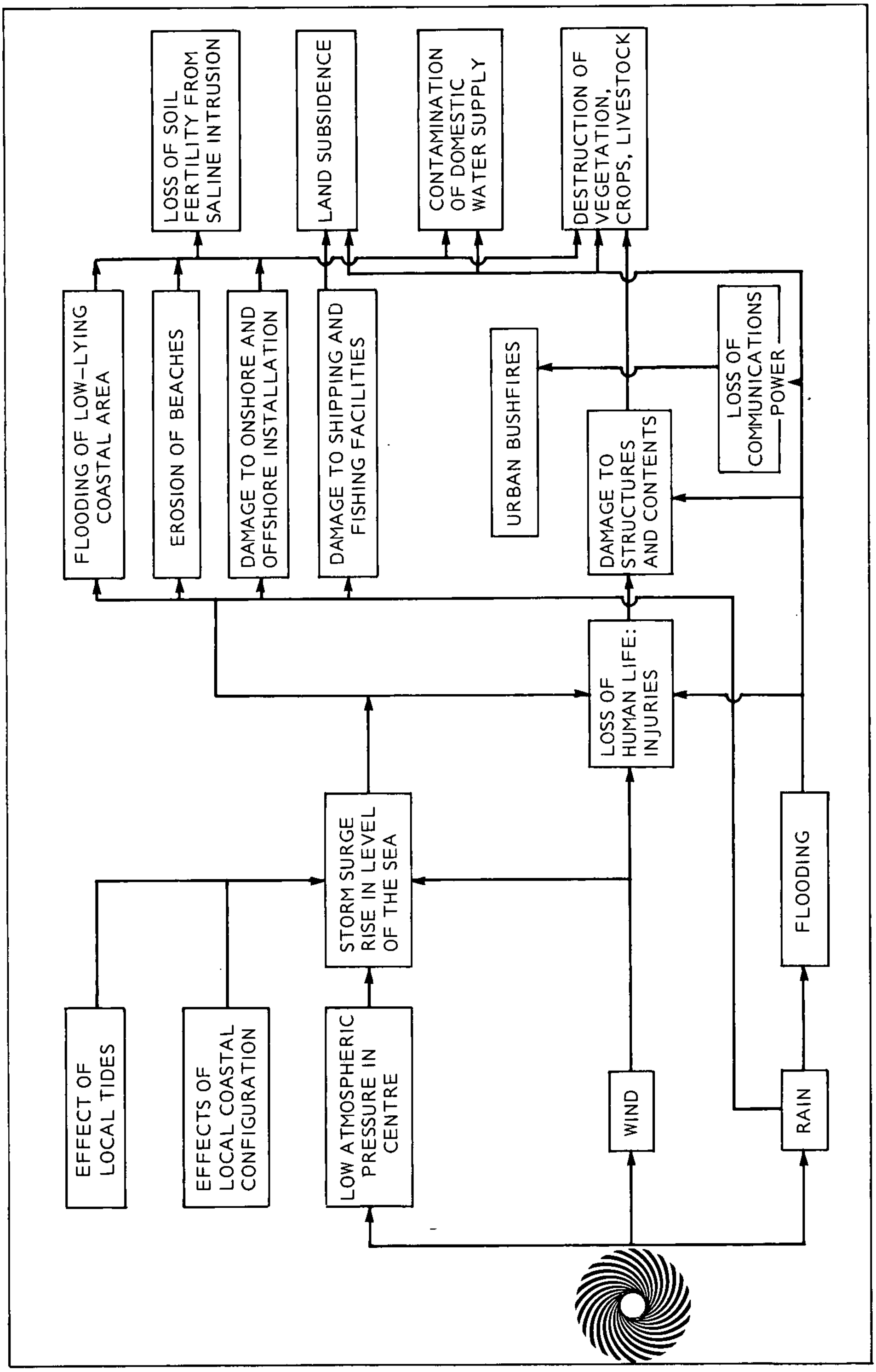

Fig. 1 Types of potential damage accompanying tropical cyclones (after White 1974).

variations in effects may occur particularly in respect of the magnitude of storm surges. Fig. 2 shows the global occurrence and areas affected by tropical cyclones.

GLOBAL VULNERABILITY

The areas of the world most vulnerable to the socio-economic impact of tropical cyclones occur in three main categories:

(a) the densely populated fertile delta regions (e.g. Ganges delta);

(b) the island groups dependent on agricultural economies (e.g. Caribbean, Oceania, Philippines);

(c) the highly populated coastal regions developed either as residential resorts or for industrial purposes, often in higher latitudes (e.g. Japan, United States of America).

The delta regions in developing countries offer by far the highest potential for loss of life. For example nearly 90 per cent of Bangladesh is either cyclone or flood prone. It is a curious fact of geography that, with the exception of the Mississippi delta, major delta systems are also subject to great tidal ranges of up to 8 m. Substantial inundation in delta rivers and estuaries may thus occur from the combined effect of storm surge and flood rains. The physical characteristics of major delta systems are shown in Table 4.

Table 4 Physical characteristics of major river deltas and estuaries in the tropics. (Source: Pergamon *World Atlas*.)

	Drainage (km^2)	Mean Discharge ($\times$ 100 m^3 s^{-1})	Tidal Range (m)
DELTAS			
Ganges-Brahmaputra	59 520	385	5.6
Mississippi-Missouri	26 159	184	0.5
Mekong	50 000	110	3.5
Irrawaddy	19 943	130	5.5
Zambesi	7148	71	4.0
Indus	7770	55	4.2
Huang Ho	1940	33	3.4
ESTUARIES			
Amazon	-	1800	5.7
Yangtze	-	340	4.2

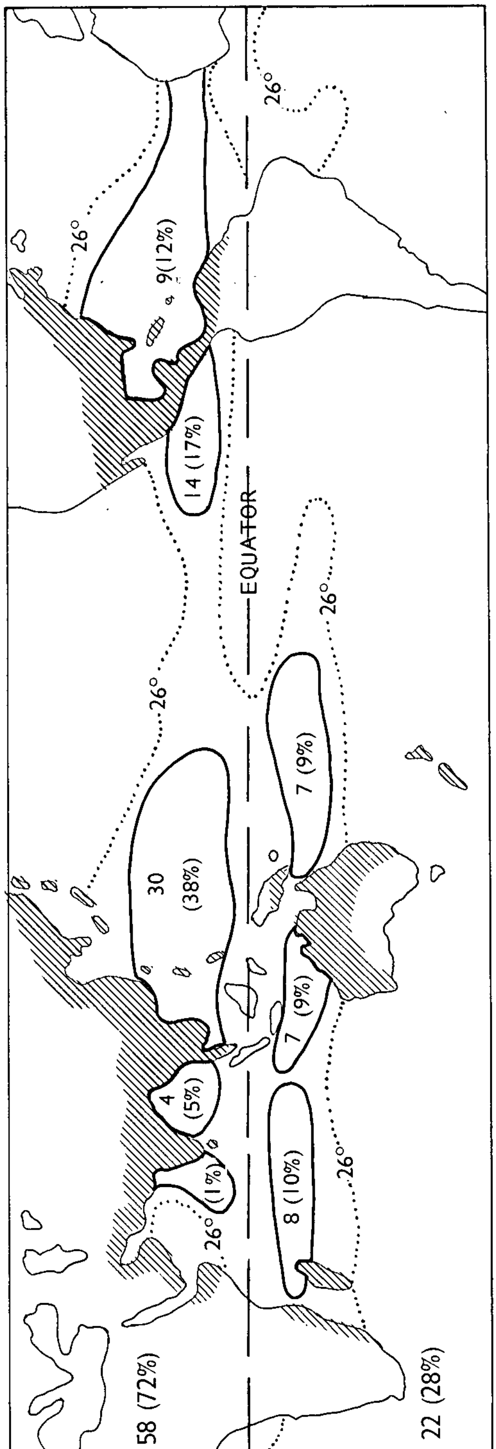

Fig. 2 The global occurrence of tropical cyclones (after Gray 1975). Land areas affected by cyclones are shown hatched.

The regional vulnerability and impact of tropical cyclones is illustrated by reference to the following figures:

Fig. 3 The hazard potential in Bangladesh, which includes much of the Ganges delta and low-lying islands;

Fig. 4 The mean annual frequency with which severe tropical cyclones of typhoon intensity traverse 5° grid points in the South China Sea east of the Philippines (after Crutcher and Quayle 1974);

Fig. 5 A summary of the most damaging tropical cyclones to have impacted islands in Oceania during a 40-year period. Tracks of several historically important cyclones are indicated (after Kerr 1976);

Fig. 6 Tracks of more severe tropical cyclones in the Australian region in the most recent decade causing damage estimated at about $A2000 million;

Fig. 7 A comparison of the frequency of severe tropical cyclones' impact on two remote islands, Guam, in the western Pacific, and Mauritius, in the western Indian Ocean.

THE ANNUAL COST OF DAMAGES

The annual cost of tropical cyclone damage globally is estimated to be about US$6000 million in today's currency. Damage estimates are maintained regularly in the USA and in nations forming the Economic and Social Commission for Asia and the Pacific (ESCAP). The June quarterly issue of the *ESCAP Water Resources Journal* (1978) provides annual accounts and summaries of the economic damage in various categories, as well as casualties. The journal also provides inventories of damage and casualties in respect of selected tropical cyclones. Table 5 provides an example of two recent typhoons in Japan and Vietnam.

Table 5 Damage inventories of two typical tropical cyclones. (Source: ESCAP, *Water Resources Journal* 1978.)

TYPHOON SARAH (Vietnam)

21 July 1977

Crop Loss (Tons)	220 000
Homeless Persons	99 110
Dwellings Destroyed & Damaged	50 520
Warehouses	12 278
Schools, Public Buildings	2202
Trees Destroyed	>1 million
Electricity Poles Torn Down	6684
Electricity Wires (km)	584
Small Craft Damaged	122
Estimated Loss	US$100 000 000

	AREA	POPULATION	
TOTAL	141 000 km^2	75 M	
Cyclone Prone	43 000 "	23 M	
Flood Prone	82 000 "	49 M	
Delta Drainage	60 000 "		
Tidal Range	5.6 m		
Annual Frequency	Tropical Cyclone	2	(one surge)
Tornadoes		2	
Floods		3	(80% rain 20% sea)

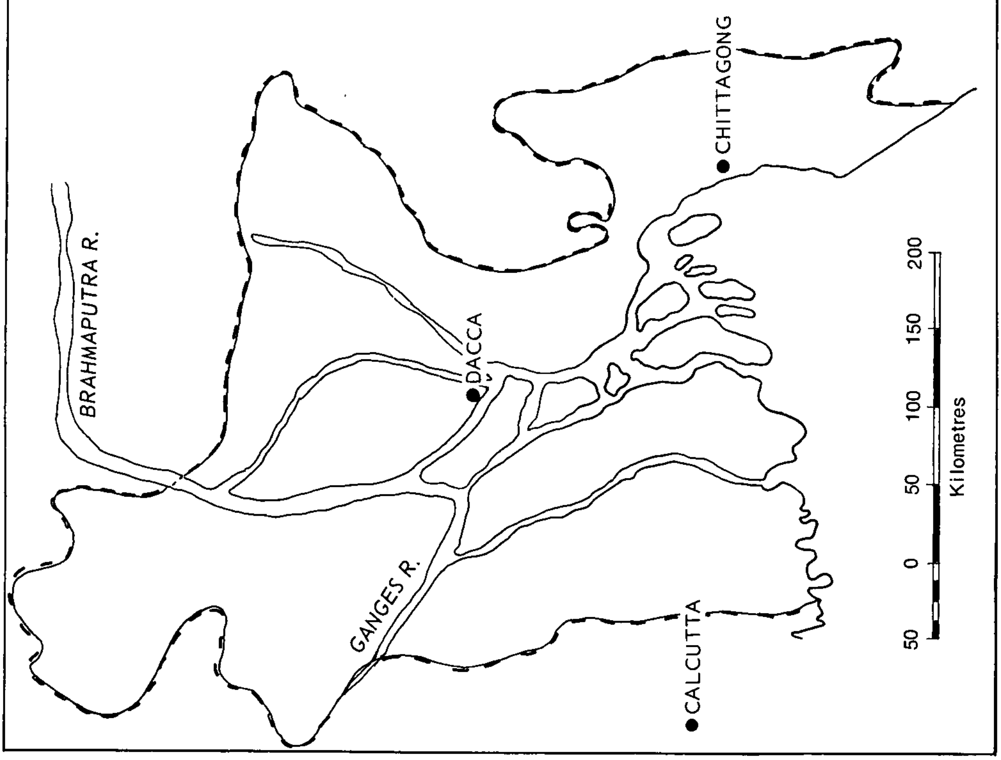

Fig. 3 The hazard potential in Bangladesh which includes much of the Ganges delta and low-lying islands.

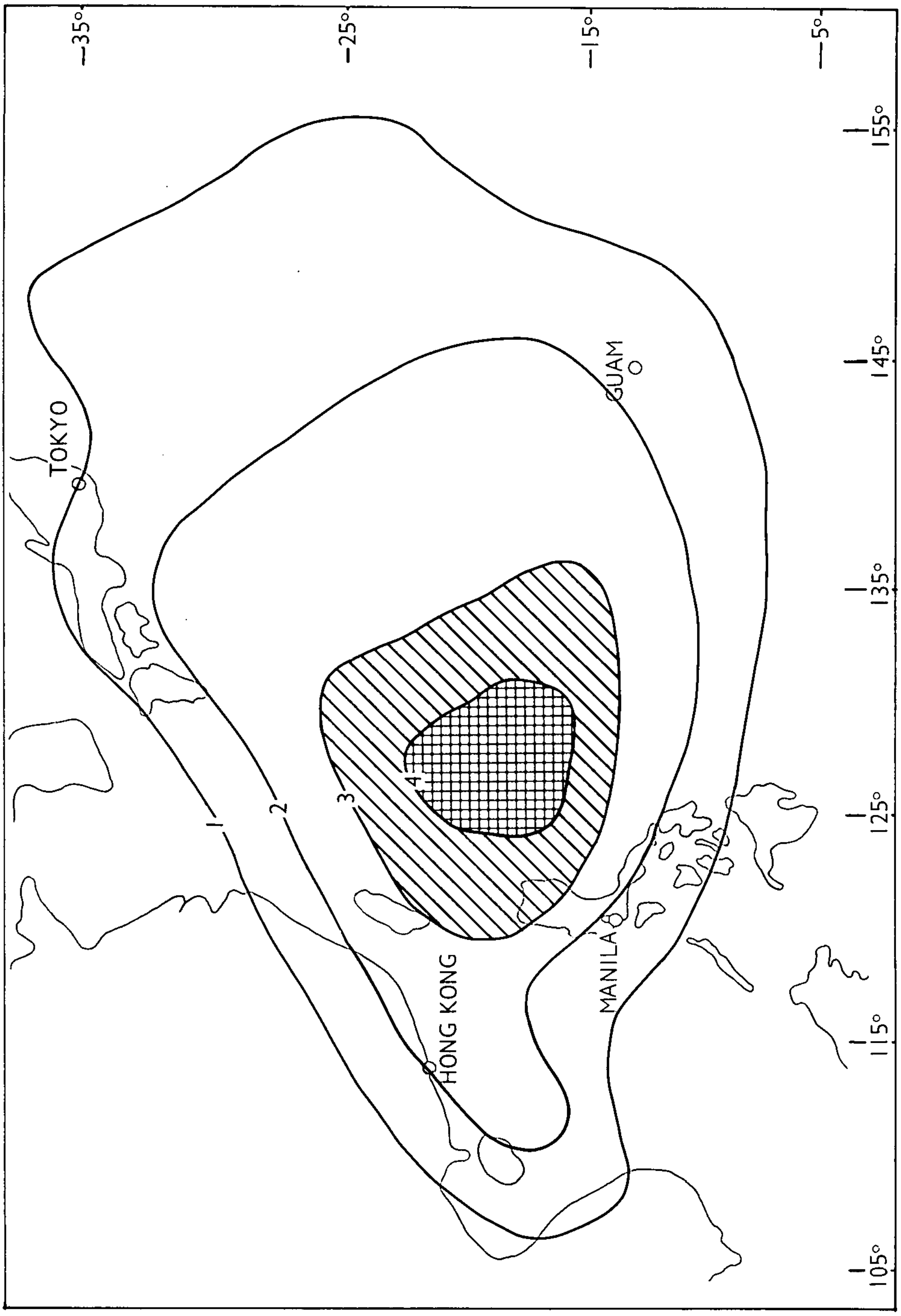

Fig. 4 The mean annual frequency with which severe tropical cyclones of typhoon intensity traverse 5° grid points in the South China Sea east of the Philippines (after Crutcher and Quayle 1974).

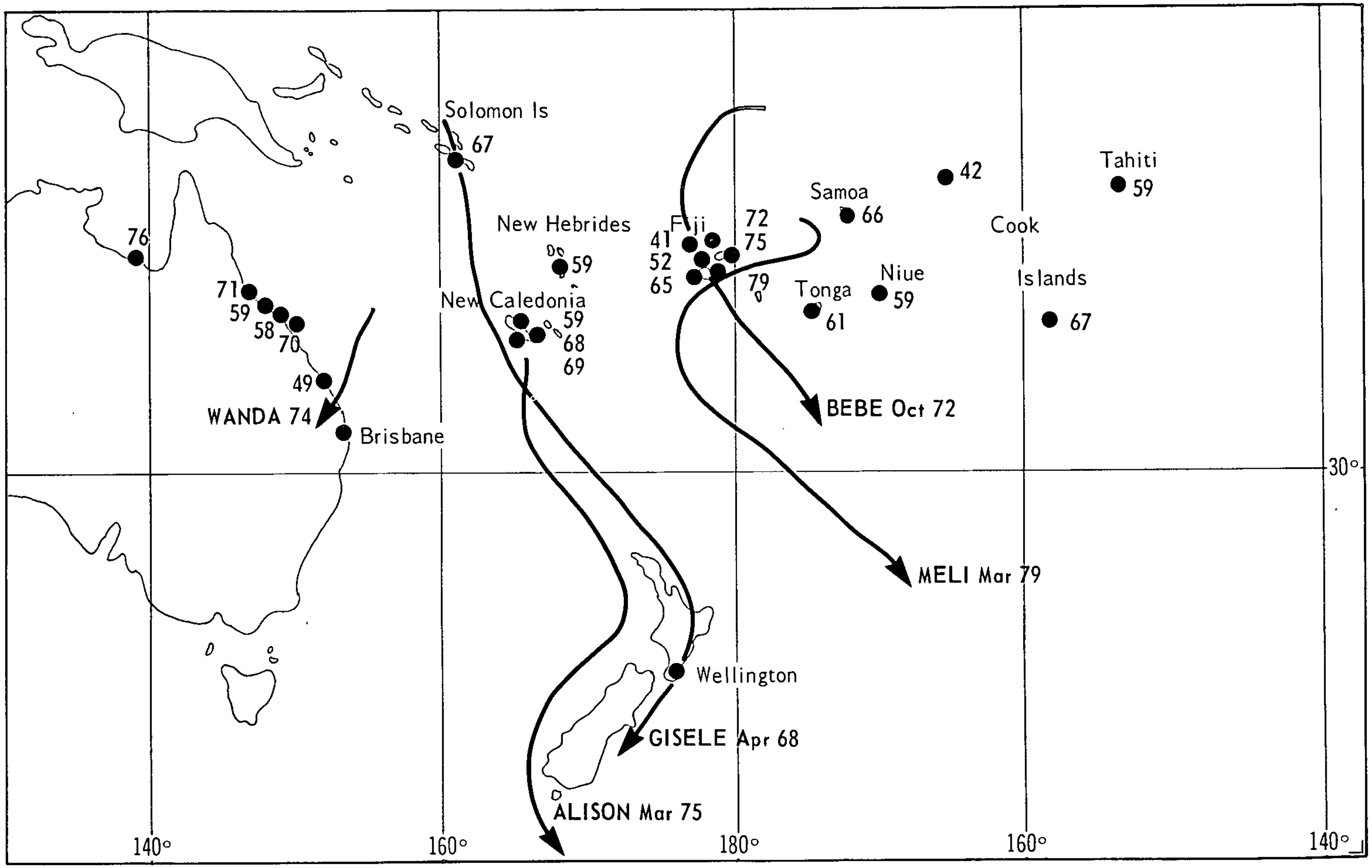

Fig. 5 A summary of the most damaging tropical cyclones to have impacted islands in Oceania during a 40–year period. Tracks of several historically important cyclones are indicated (after Kerr 1976).

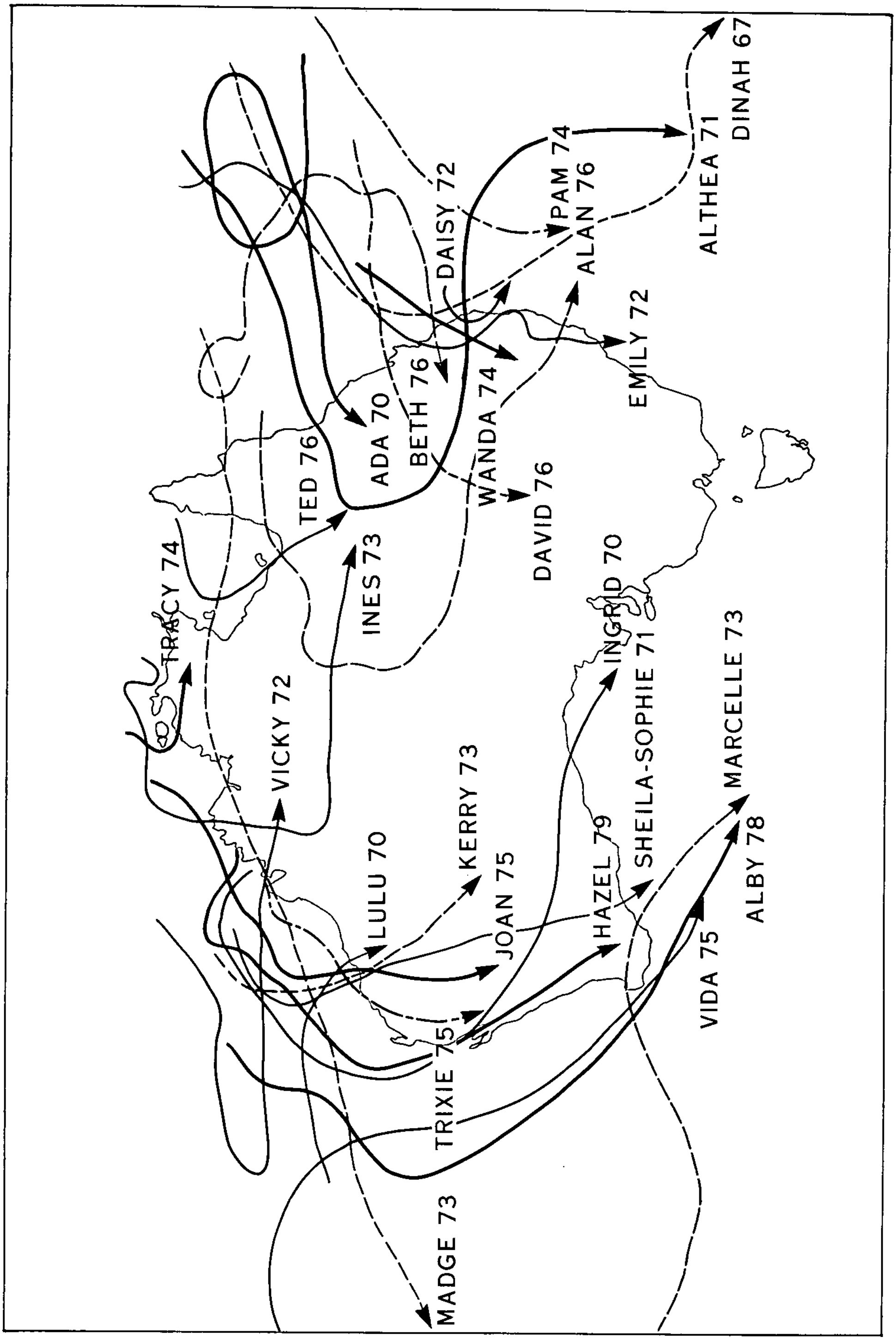

Fig. 6 Tracks of more severe tropical cyclones – in the Australian region in the most recent decade – causing damage estimated at about $A2000 million.

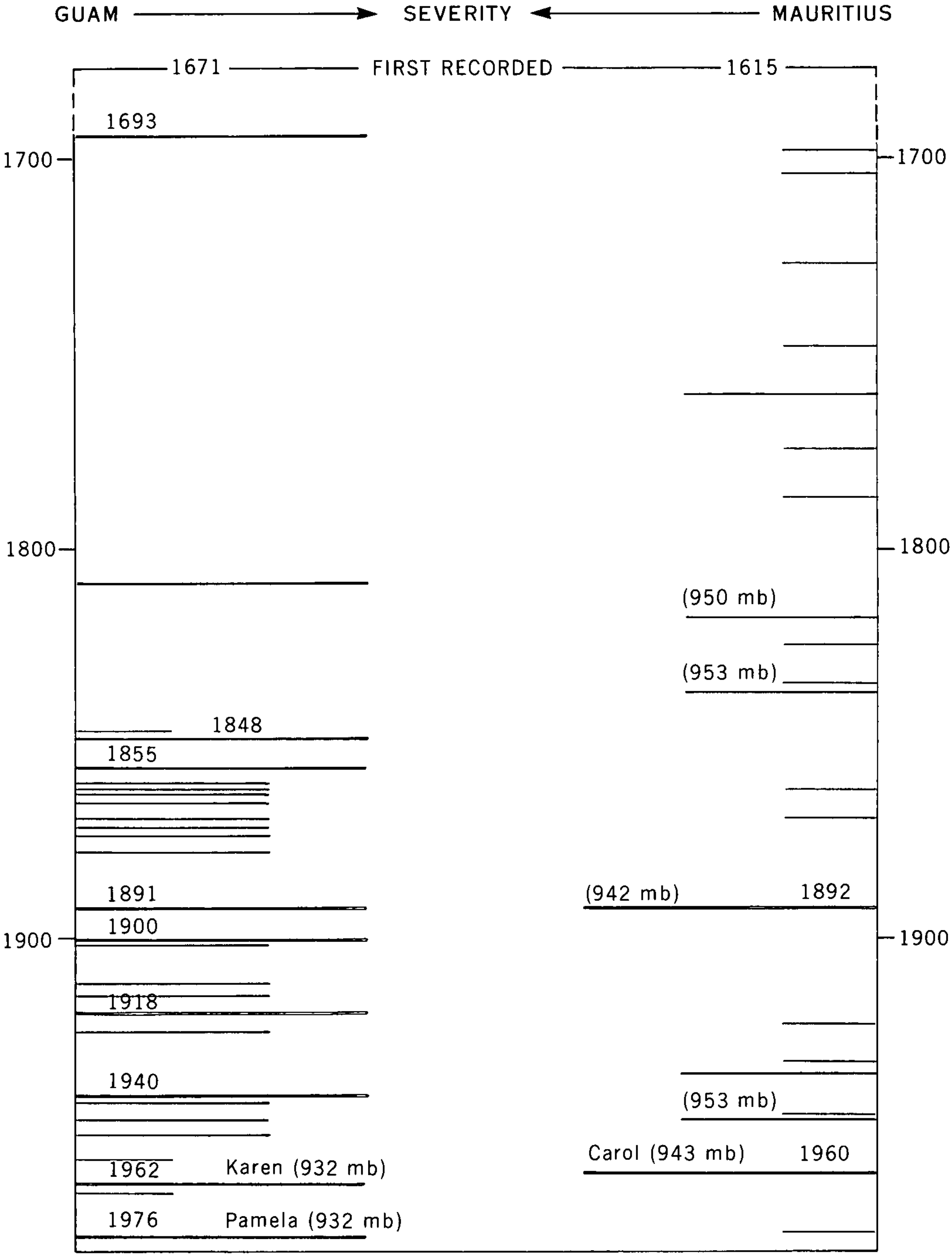

Fig. 7 A comparison of the frequency of severe tropical cyclones impact on two remote islands, Guam, in the western Pacific, and Mauritius, in the western Indian Ocean.

TYPHOON FRAN (Japan)

8 to 12 September 1976

Casualties - Deaths			224
Injuries			531
Houses Destroyed			1 807
Damaged			584 368
Buildings	"		15 586
Farmlands	"	ha	124 090
Road sites	"		43 960
Bridges	"		913
Rail sites	"		747
Landslides	"		9 436
Embankments Breached			41 417
Small craft Damaged			140

Figure 8 provides the average annual number of deaths and damage (based on the years 1964 to 1977, using 1975 prices) throughout the ESCAP region. The average annual number of deaths is 15 500 and the damages bill US$2631 million. Account needs to be taken of the infrequent major catastrophes (such as Bangladesh 1970 and Darwin 1974) that can distort decadal figures. On the other hand US researchers claim that initial estimates of damage often turn out to be understated by a factor of 3 or 4 when viewed in retrospect. The damages bill in Australia has amounted to about $A2 million million in the last 10 years but that caused by cyclone Tracy and the Brisbane floods, both in 1974, account for about half this total.

SOCIAL EFFECTS OF TROPICAL CYCLONES

What of the effects on the survivors of a disaster, their happiness, economic well-being, self-adjustment and subsequent life style? And what, for example, has been the effect of various emergency decisions such as mass evacuation? In the week immediately after cyclone Tracy in Australia in 1974 about 80 per cent of the population of the city of Darwin of 47 000 had left: 23 000 (mostly women and children) in a massive airlift by Boeing 747 aircraft - one of which carried 694 persons - to southern capitals and another 15 000 left by road.

Subsequently, justified or not, there was strong criticism of such action. One well-known Darwin citizen, a lady MP, has written 'For a few weeks Darwin was virtually a town without children and I realised then just what a dreadful act the Pied Piper had perpetrated on Hamlyn. A town without children is a dead town and officialdom nearly accomplished that which cyclone Tracy could not do, that is to kill Darwin ...' (Lawrie 1977).

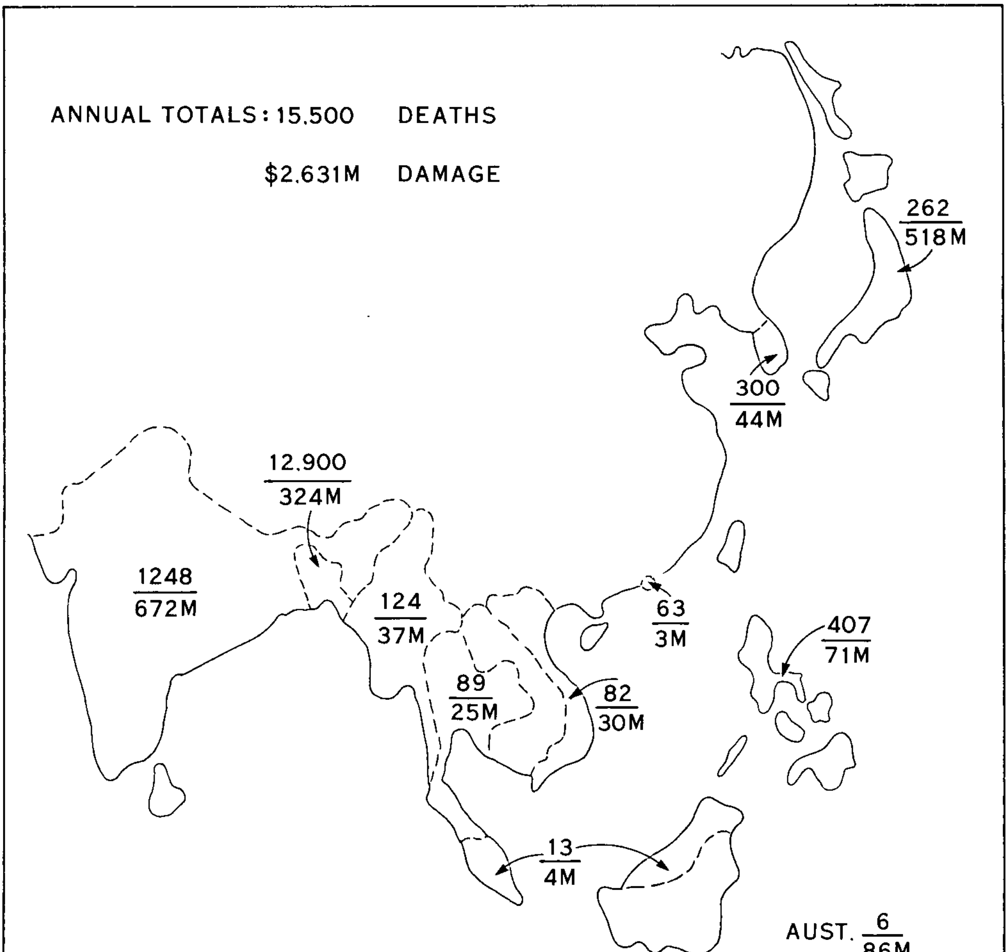

Fig. 8 The average annual tally of deaths and damage in countries in the ESCAP region (1965–77).

Social scientists at the University of Queensland have reported in their surveys on the social adjustment of Darwin citizens conducted some 7 to 10 months after cyclone Tracy. The respondents to the survey were categorised as those who, (a) were not evacuated, (b) returned after evacuation, and (c) did not return. In general it was found that those who were not evacuated subsequently underwent less stress, were less emotionally disturbed, were re-employed quicker and led more positive lives than those who did not return. The evacuees who returned were in the middle ground. The researchers concluded 'sufficient evidence has been accumulated to suggest that mass evacuation may pose more problems than it solves and that greater use of the victim's resources might not only speed up the reconstruction but also reduce some of the psychological stress on the victims themselves' (Western and Milne 1979). Table 6 provides data from one of the surveys conducted by the authors on personal re-adjustment to the effects of cyclone Tracy.

A METHODOLOGY FOR STUDY OF LONG-TERM IMPACT

A rigid methodology is needed to effectively assess the long term socio-economic impact of disasters. One of the very few such approaches has recently been published by researchers at Northwestern University sponsored by the US National Science Foundation (Friesema 1979). The group has attempted to measure the flow-through model of an urban economy for up to 5 years prior to and following a disaster in an attempt to measure the difference between observed effects and those that could have been expected to occur through normal secular change.

The group has also endeavoured to distinguish between the magnitude of an event (e.g. maximum wind velocity) and its severity (namely the losses at initial impact, the recovery phase in restoration of essential services, and the costs involved in eventual return to normalcy). The methodology was applied to four disasters in the USA; an earthquake, a flood, a hurricane and a tornado.

Although partly foiled by lack of socio-economic data to fully test the model, nevertheless a methodology has been established for the future. The group concluded from its initial studies that:

(a) none of the economic indicators on which we have collected data suggests that natural disasters leave profound lingering effects on these local economies; and

(b) the social changes that are attributable to the natural disasters striking the four communities seem to be quite mild and beneficial, to the extent that they occur at all. We could find no social patterns that were changed in a way that we call permanent or that seemed to outlast the reconstruction period.

Research on the impact of tropical cyclones in a well regulated capital-intensive economy cannot adequately represent the impacts of disasters in countries whose economies are largely based on labour-intensive rural economies. In the latter, typified by the delta regions and tropical islands, tropical cyclone disasters are but the harsh end of the normal spectrum of weather disturbances that in kinder mood bring the sought after benefits of gentle rain to a fertile soil. Disasters causing devastation to crops or plantations in one country can lead to a boom in prices in neighbouring countries. The recent hurricanes David and Fredric were reported to have reduced the economy of the Dominican Republic from an anticipated 5.6 per cent

Table 6 Readjustment to personal stresses among three groups of citizens affected by cyclone Tracy in Darwin (1974). Data in percentages. (Source: Symposium on Natural Hazards in Australia, 1976.)

	Stayers (n=90)			Returned evacuees (n=107)			Non-returned evacuees (n=219)		
	Before	Now	*Diff.*	Before	Now	*Diff.*	Before	Now	*Diff.*
A restless person	56	51	5	57	46	11	64	37	27
Worried about the future	58	44	14	62	41	21	71	32	39
A smoker	51	53	-2	63	63	0	57	58	-1
Nervous and depressed	79	62	17	61	46	15	76	51	25
Prone to headaches	86	80	6	72	65	7	72	63	9
Fond of most alcoholic beverages	34	33	1	45	43	2	38	37	1
Troubled by skin complaint	76	74	2	85	84	1	81	75	6
Lacking in confidence	72	69	3	61	58	3	68	53	15
Taking pain-killing drugs	92	89	3	91	91	0	88	84	4
Lacking in energy	61	51	10	56	53	3	72	56	16
Finding the children difficult	41	39	2	59	53	6	40	30	10
Worried about my marriage	59	59	0	73	76	-3	76	76	0
Using sedatives	96	96	0	91	89	2	92	85	7
Without appetite for food	82	85	-3	83	81	2	87	86	1
Short tempered	54	48	6	52	46	6	56	43	13
Troubled by indigestion	87	82	5	92	91	1	90	86	4
Overweight	68	64	4	62	61	1	69	62	7
Asthmatic	96	96	0	93	92	1	95	94	1
Underweight	83	83	0	92	90	2	89	88	1
Having bowel trouble	93	90	3	94	94	0	95	90	5
Taking it out on the children	50	49	1	73	68	5	57	45	12

growth in Gross Domestic Product to a drop of 2 per cent at an internal cost of RD$720 million; whereas even Australian sugar prices have been forecast to rise due to the Caribbean disaster.

Some disasters, not truly catastrophic in their impact, can mislead a community into a sense of false security against a future greater threat. Again a major disaster may also prove to be an eventual blessing in disguise. What, for example, could have been the impact of a cyclone Tracy on an eventual Darwin population of about 200 000 that continued to adopt the same sub-standard building codes and tropical-style house designs that applied prior to 1974?

FUTURE TRENDS

Model studies in the USA supported by the National Science Foundation have projected the likely trend in building damage, should past events such as the San Francisco earthquake of 1906, hurricane Camille in 1969 and the Agnes floods of 1972 recur either in today's conditions or those likely to occur in the year 2000. Some conclusions reached (J.H. Wiggins Company) are these:

(a) although river floods cause the most damage to buildings today - about US$3000 million annually - hurricane wind/storm surge is expected to become the number one hazard by the year 2000 unless appropriate mitigations are applied. Hurricane damage is projected to grow from US$2000 million to US$5000 million annually due to population growth and movement, coastal development and higher construction values;

(b) if hurricane Camille repeated its 1969 devastation in the year 2000 building damage could top US$4000 million (1978), and it could cause 200 to 400 deaths and 20 000 to 40 000 injuries. But if most effective mitigations were to be applied beginning in 1980, damage could be reduced by over US$1000 million, 50 to 100 lives saved and 5000 to 10 000 injuries avoided.

One senses that the same relative savings could apply in Australia. Improved warning systems in the USA have reduced the number of deaths per US$10 million property damage from 166 at the turn of the century to about two per US$10 million today (prices not adjusted).

WORLD-WIDE TREND

The world-wide picture is less hopeful.

Estimates of population growth show that the world's population by 2050 will be more than 4 times greater than in 1950, much of the increase being located in coastal regions subject to tropical cyclones, either in vulnerable delta regions, highly popular recreational resorts, or major industrial cities and ports. Table 7 provides United Nations Organisation estimates of global population trends.

Table 7 United Nations estimate of world population trends and a selection of population densities in countries affected by tropical cyclones. (Source: *Encyclopaedia Brittanica.*)

Year (AD)	Est. Population (millions)
1000	340
1650	545
1800	907
1950	2509
2000	6100
2050	11 000

UN Estimates 1969 (millions)

Country	1970	2000
Developed	1082	1441
Less Developed	2510	6129

Maximum Densities 1973 (km^2)

Hong Kong	4032	Philippines	136
Macau	16 536	Hati	162
Japan	289	Guam	173
Sth Korea	341	Mauritius	434
Bangladesh	496	Tonga	160
Sri Lanka	204	New Zealand	11
Taiwan	434	Barbados	568
Kerala St (Ind)	586		

FUTURE MAJOR DISASTERS

Finally an estimate of the tracks and possible landfall of the most potentially devastating tropical cyclones, which could occur in the next 25 to 50 years, is presented in Fig. 9. Should super-tropical cyclones (typified by central pressures of less than about 920 mb with mean winds in excess of 130 knots) follow these tracks and make landfall under conditions maximising storm surge, then catastrophes comparable with that of Bangladesh (1970) or exceeding that of Camille (1969) must be expected. The evidence points to a growing toll of death and damages made unavoidable, partly due to limitations on national resources to apply effective mitigation measures, and partly due to a lack of understanding of the vulnerability of certain areas to the effects of cyclones.

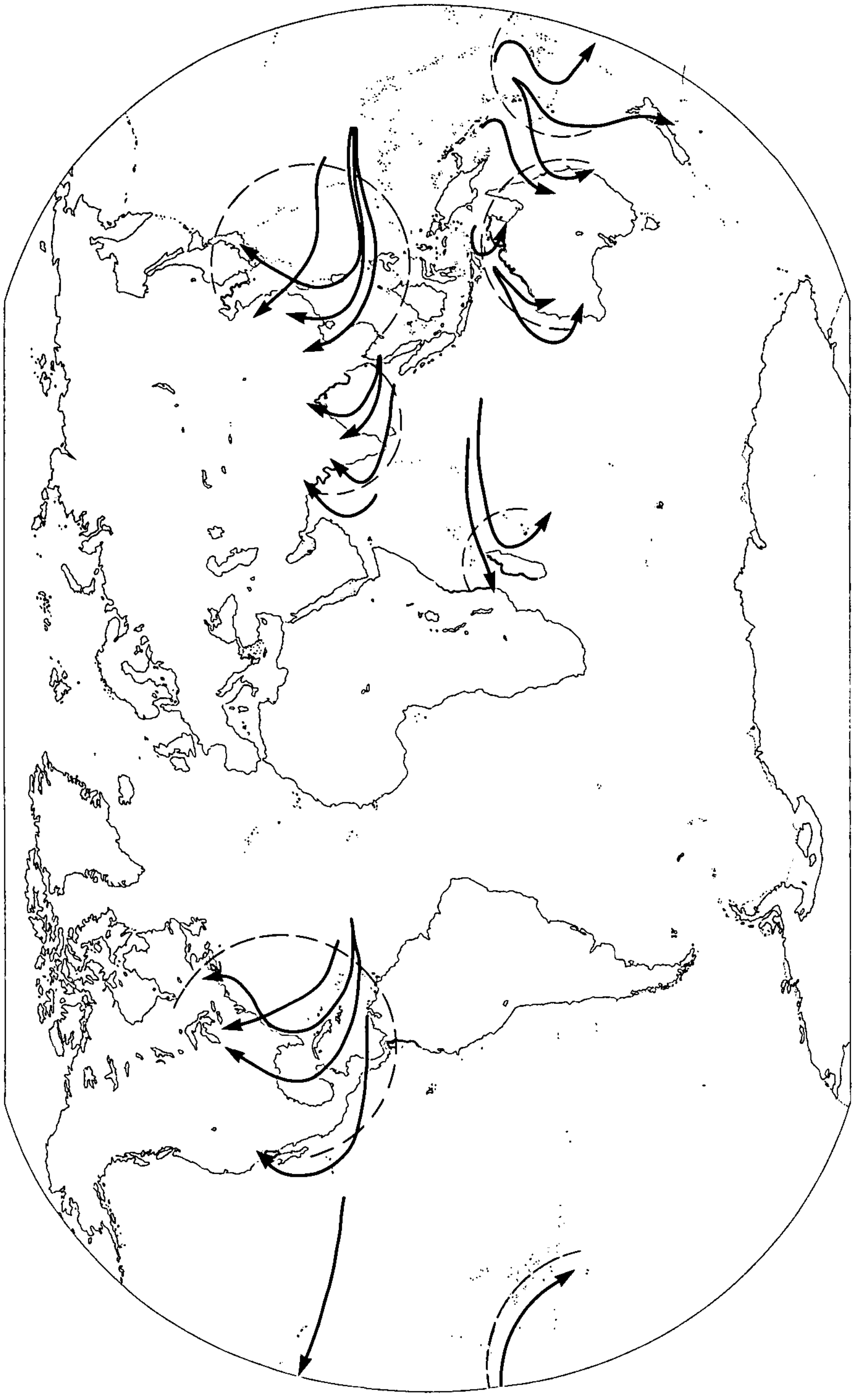

Fig. 9 Postulated tracks of super tropical cyclones with potential to cause major catastrophes in coming decades. Dashed arcs represent regions of maximum vulnerability to tropical cyclones. Coastlines where tidal range exceeds 4m are emphasised.

CONCLUSION

The prime responsibility of the meteorologist is to fully exploit new technological aids for the monitoring of tropical cyclones, and reduce errors in 12 to 24-hour prediction. These improvements in warnings will be essential just to counteract the increased potential for loss of life and damage impact as population and capital investment grows in vulnerable coastal areas. Increased international co-operation in all aspects of tropical cyclone research and operation, such as manifested by the attendance at this conference, will make a vital contribution in the application of the limited scientific resources available. Happy indeed should be the meteorologist with such important tasks to perform.

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