Risk factors for mortality in the Bangladesh cyclone of 1991

C. Bern,[1] J. Sniezek,[2] G.M. Mathbor,[3] M.S. Siddiqi,[4] C. Ronsmans,[5] A.M.R. Chowdhury,[6] A.E. Choudhury,[4] K. Islam,[7] M. Bennish,[8] E. Noji,[9] & R.I. Glass[1]

Cyclones continue to pose a dangerous threat to the coastal populations of Bangladesh, despite improvements in disaster control procedures. After 138 000 persons died in the April 1991 cyclone, we carried out a rapid epidemiological assessment to determine factors associated with cyclone-related mortality and to identify prevention strategies. A nonrandom survey of 45 housing clusters comprising 1123 persons showed that mortality was greatest among under-10-year-olds (26%) and women older than 40 years (31%). Nearly 22% of persons who did not reach a concrete or brick structure died, whereas all persons who sought refuge in such structures survived. Future cyclone-associated mortality in Bangladesh could be prevented by more effective warnings leading to an earlier response, better access to designated cyclone shelters, and improved preparedness in high-risk communities. In particular, deaths among women and under-10-year-olds could be reduced by ensuring that they are given special attention by families, neighbours, local authorities, and especially those in charge of early warnings and emergency evacuation.

Introduction

The Bay of Bengal is one of the most dangerous tropical cyclone basins in the world, with severe storms occurring in the spring and autumn (*1*); for example, the devastating cyclone of 1970 (*2*). Since 1960, at least 0.5 million lives have been lost in a total of eight cyclones in Bangladesh (*3, 4*) (Table 1).

In response to the cyclone of November 1970, a sophisticated early warning system was established in Bangladesh. This system provides weather data from a U.S. government satellite to the Bangladesh National Storm Warning Centre, which then transmits radio warnings to areas in danger (*5*).[a] Local communities are alerted by the volunteers of the Bangladesh Red Crescent Society. Theoretically, satellite warnings can reach the communities at risk in a matter of hours after cyclones are identified.

The cyclones of 1970 and of 1985 also prompted an international effort to build cyclone shelters in vulnerable coastal areas. A total of 311 shelters, with an estimated total capacity of 350 000 persons, now stand in the coastal areas of Bangladesh (*6*).

On 29 April 1991, a severe cyclone was visualized by satellite over the Bay of Bengal approaching the coast of Bangladesh (Fig. 1). On the evening of April 29 the cyclone hit the coast of Bangladesh 50 km south of Chittagong, with sustained winds of 255 km per hour, greater than those of the 1970 cyclone, and caused a 6-m storm surge.[b] Despite the early warning, the 1991 cyclone resulted in an estimated 138 000 deaths on the offshore islands of Kutubdia and Sandwip, and in the coastal lowlands from Chittagong to Cox's Bazar.

In the aftermath of this disaster, we conducted a rapid epidemiological assessment of two cyclone-

[1] Respiratory and Enteric Virus Branch, Division of Viral and Rickettsial Diseases, National Center for Infectious Diseases, Mailstop G-04, Centers for Disease Control, Atlanta, GA 30333, USA. Requests for reprints should be sent to Dr Bern at this address.

[2] National Center for Injury Prevention and Control, Centers for Disease Control, Atlanta, GA, USA.

[3] Tolaram College, Narayanganj, Bangladesh.

[4] Program for the Introduction and Adaptation of Contraceptive Technology, Dhaka, Bangladesh.

[5] Harvard School of Public Health, Boston, MA, USA.

[6] Bangladesh Rural Advancement Committee, Dhaka, Bangladesh.

[7] UNICEF, Dhaka, Bangladesh.

[8] Tufts University School of Medicine, Boston, MA, USA.

[9] Division of Environmental Hazards and Health Effects, National Center for Environmental Health, Centers for Disease Control, Atlanta, GA, USA.

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[a] **Mozher-ul-Islam.** *Disaster warning and dissemination system in Bangladesh.* Paper presented at: *Disaster Preparedness Seminar, 1981.* Dacca, Bangladesh Meteorological Department.

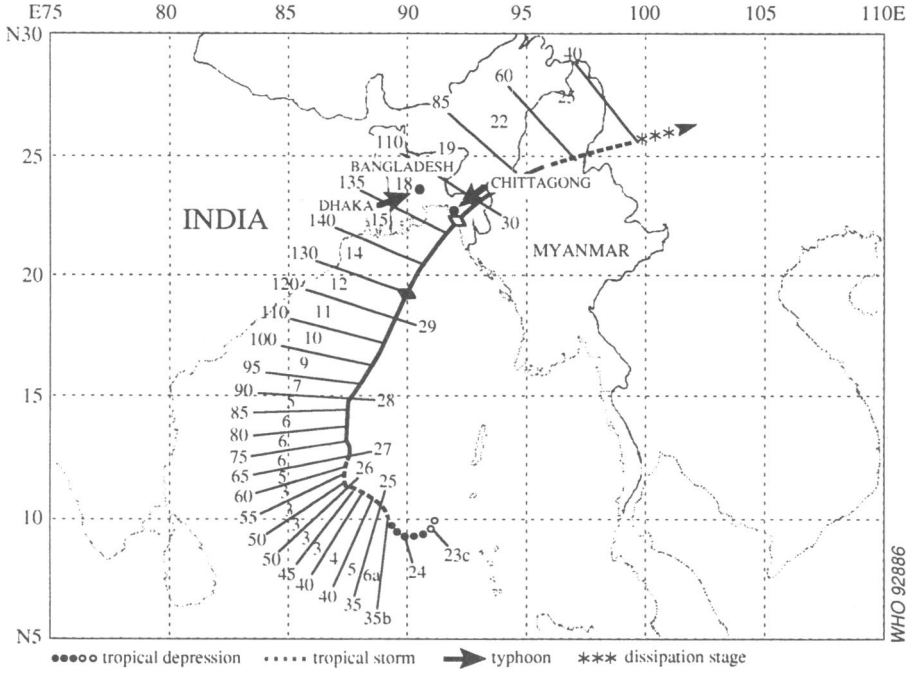
[b] *Tropical storm 02B.* Guam, Joint Typhoon Warning Center, 1991. Unpublished report.

Table 1: **Cyclones in Bangladesh (East Bengal) since 1960 associated with ≥1000 deaths** [a]

	No. of deaths	Areas most affected
October 1960	6000	Offshore islands, Barisal to Chittagong
November 1960	15 000–20 000	Chittagong
May 1963	10 000–20 000	Offshore islands
May 1965	15 000–36 000	Barisal, Noakhali
November 1970	225 000–500 000	Patuakhali, Noakhali, northern offshore islands
April 1978	1000	Unspecified
May 1985	11 000	Offshore islands, Noakhali
April 1991	138 000	Chittagong to Cox's Bazar, eastern offshore islands

[a] Source: ref *3, 4.*

Fig. 1. **Official best-track of the tropical cyclone 02B** (prepared by the U.S. Naval Oceanography Command Center/Joint Typhoon Warning Center, Guam). Spokes and line represent 6-hour best-track position; a—speed of movement in knots; b—surface wind speed in knots; c—position at 00 h 00 GMT on 29 April 1991.



devastated areas to identify factors that might have determined why some people survived and others did not (*7–9, 12, 13*). For this purpose we investigated how the existing programmes of early warning, shelter building, and preparedness could be improved and attempted to identify other strategies that could prevent cyclone-related mortality in the future.

Survey methods

The survey was conducted in two coastal districts of Bangladesh: Chakaria on the mainland, and Kutubdia, an offshore island. Both these areas were severely affected by the cyclone, losing 10% or more of their population, and were accessible using local transport. Most inhabitants lived in houses made of bamboo and thatch (*kutcha*), but a few affluent members of the community lived in houses made of brick or concrete (*pukka*). Commercial markets and community buildings are generally *pukka*. The dwellings stand in clusters of 2–10 houses, representing an extended family.

We hypothesized that survival would be related to the ability of individuals to reach a reinforced

structure in good time, and would thus be associated with housing type, timely receipt and understanding of the cyclone warning, and how early in the course of the storm individuals sought shelter. The study was carried out in areas that were severely affected to maximize the amount of data collected on risk factors for mortality (*7*). The sample was therefore not population-based, and excluded areas that could not be reached by local transport at the time of the survey. No attempt was made to estimate total mortality from the cyclone.

Villages were selected from the areas with the highest reported mortality, and a convenience sample of dwellings and former dwelling sites surveyed. The primary informant was the head of the household first encountered in the cluster of dwellings. Information was collected for two to four adjacent houses from each primary informant, consisting of 25–30 individuals per cluster. This design permitted us to collect the maximum amount of data efficiently and to obtain information on some households in which all family members had died, a group that might otherwise have been missed and whose nonrepresentation could have biased the survey. The primary informant was asked to list all members in his household and the adjacent households prior to the cyclone, the age and sex of each individual, and whether that person had survived the cyclone. All primary informants were asked about their understanding of the cyclone warning, how many hours before the cyclone's impact the warning was heard, their response to the warning, and the reasons for any non-response.

Information was also elicited on the location of family members prior to and during the cyclone and on the specific circumstances surrounding any death. We recorded the location of family members prior to hearing the cyclone warning, after the warning, at the first approach of the storm surge, and just after its impact. Locations were classified as follows: a "safe shelter" — any *pukka* structure — or "at risk" — a category that included traditional *kutcha* houses, and out-of-doors, where many people clung to trees or attempted to escape to high ground.

Five cyclone shelters in affected areas were visited and their accessibility and the population who sheltered in them during the cyclone were ascertained by interviewing people living near them.

Results

From 14 June to 21 June 1991, four two-person field-teams surveyed a total of 45 clusters (18 in Chakaria and 27 on Kutubdia), comprising 135 households with a total population of 1123 individuals, whose age and sex distribution reflected that of the Bangladeshi population as a whole. A total of 162 individuals (14%) from the population surveyed died during the cyclone. Mortality was greatest among children aged <10 years (26%; P <0.0001) and lowest for males aged >10 years (4%; P <0.0001); for females mortality increased with age, reaching 31% for those aged >40 years and 40% for those aged >60 years (P <0.01 and P <0.0001, respectively).

Type of housing and shelter-seeking activity were directly related to the risk of dying in the cyclone (Fig. 2). No deaths occurred among the 27 individuals (2%) who lived in *pukka* houses or remained in *pukka* public buildings for the duration of the cyclone. However, 1094 individuals (98%) were not in a safe shelter prior to the cyclone warning. In response to the warning, which most respondents reported hearing 3–6 hours prior to the storm surge, only 40 individuals (4%) sought and reached safe shelter. When the flood waters first reached the area 10–60 minutes before the storm surge, 151 persons (13%) were in safe shelter. In all, 385 persons (33%) had reached safe shelter by the moment of impact of the storm surge; none of these persons died. In contrast, of 736 persons at risk, 162 (22%; P <0.0001) drowned in the flood waters.

A small fraction of the increased mortality among older women, but not children, could be explained by their failure to reach shelter. Only 22% of women aged ≥40 years reached safe shelter, compared with 35% of men in this age group and 34% of children (P <0.05; Fig. 3). However, if 35% of women had reached safe shelter, only a 16% reduction in their mortality would have resulted. Among all respondents at risk, females still experienced excess mortality; 46 (21%) of 222 females aged >10 years died, versus 17 (7%) of 258 males in the same age range (P <0.0001). Thus, the increased mortality among women and children was not caused by shelter access alone, but was more probably related to factors such as physical size, strength, and endurance.

Of 736 persons at risk at the time of the cyclone impact, 285 were swept away in the storm surge; of these, 112 (39%) died. Another 179 persons were able to float on some object, generally the thatch roof of their house; of these, 27 (15%) died. Mortality was 22% among those who sought high ground to escape the storm surge, and 11% among those who took refuge in trees.

People found safe shelter in different locations, according to when they decided to take action. Of the 385 people who sheltered in *pukka* buildings, 51 (13%) did so in designated cyclone shelters, 219 (57%) did so in public buildings, 25 (6%) remained

Fig. 2. **Cyclone-associated mortality and shelter-seeking behaviour before the cyclone.**

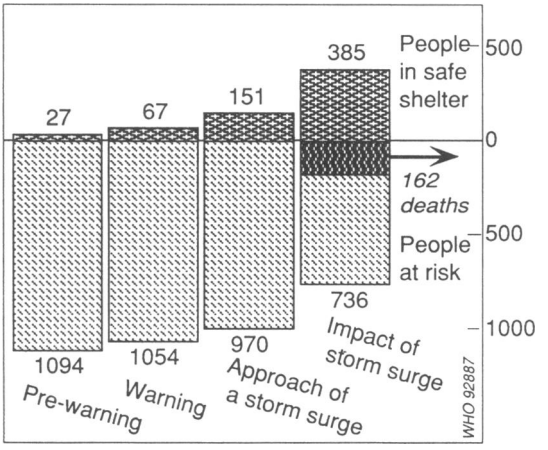
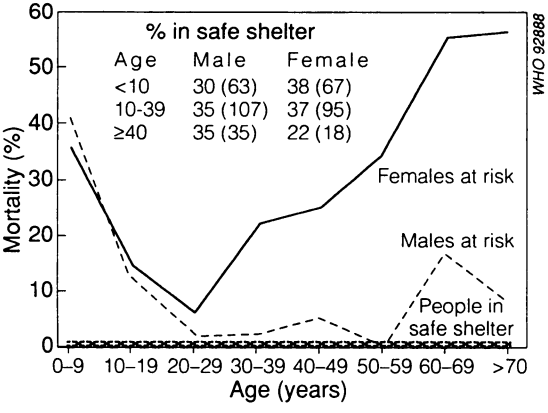


Fig. 3. **Cyclone-associated mortality, by age, sex, and shelter status at the time of impact**. Figures in parentheses are the numbers of individuals.



in their own homes, and 90 (23%) went to a neighbour's *pukka* house. No one took shelter in a neighbour's house until the impact of the storm surge, and before the impact public buildings were the most commonly used safe shelter (Fig. 4).

Although the residents of 95% of the households interviewed were aware of the cyclone warning, only 17% of these households responded to the warning by seeking shelter prior to the approach of the storm surge. For those who did not respond, 45% stated they did not anticipate that the storm would be so severe, 16% were impeded from seeking shelter by the high winds or flooded terrain, and 16% stated that they did not understand the warning. Other less frequently given reasons included fear of losing property and previous false warnings.

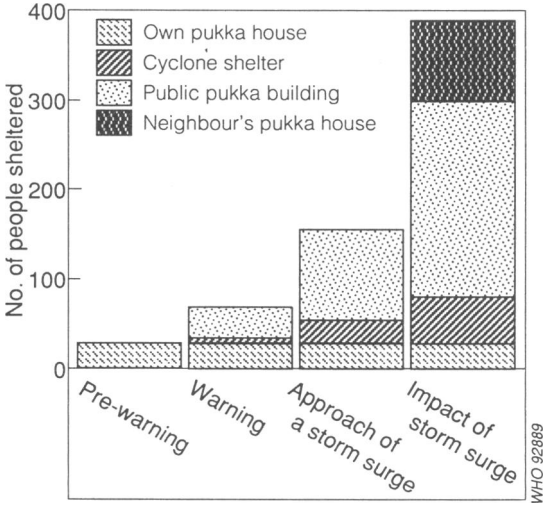
Five designated cyclone shelters in and near the survey areas were visited to assess their impact on survival. Two of the five shelters, in Chakaria and Maheshkhali, saved several thousand people each, while the other three were almost unused because high-water precluded access to them, even before the impact of the storm surge.

Discussion

Coastal Bangladesh will continue to experience severe cyclones, and as the population density increases in the areas most at risk, the extent of mortality in future cyclones will depend on the adequacy of the preventive measures taken.

In this cyclone, as in other natural disasters, children were at greatest risk of death, followed by older women (*2, 8*). Women and children are more vulnerable because of their smaller size and lack of physical strength and endurance. Nearly 40% of unsheltered children in the survey population died, negating the benefits gained by all the child survival

Fig. 4. **Use of safe shelters in four periods before the cyclone struck.**



strategies set up there in recent years. Programmes to improve access to shelters should carry a clear message that children and women must seek and attain shelter at an early stage of a disaster.

We hypothesized that people who heard the warning early would be more likely to survive. However, although nearly every household surveyed was warned about the cyclone 3–6 hours before its impact, this awareness was not associated with a decreased risk of dying.

Two features can be identified to make cyclone warnings more effective. First, warnings should be simplified and made more specific about the estimated time until impact, the areas forecast to be most affected, and the response required by the population. Second, people must be educated, through community activities, drills, and exercises, to be better prepared to take shelter.

Sheltering behaviour is a major determinant of survival (*10, 11*). No one who reached a *pukka* building died, but in most of the areas surveyed, the short time between the approach and impact of the storm surge prohibited late responders from reaching an effective shelter. Shelters should therefore be made more accessible. Three of the five cyclone shelters surveyed were virtually unused, and only a small proportion of the people surveyed who reached safe locations used cyclone shelters. By far the greatest number of people in safe shelter were those who sought refuge in small public buildings such as markets, schools, and mosques. A few private *pukka* houses also provided shelter to immediate neighbours.

The effective sheltering capacity of high-risk coastal communities could best be enhanced by increasing the number of buildings that could be used as shelters. In response to the 1991 cyclone, international relief efforts are planning to construct more cyclone shelters. All new schools, community centres, health clinics, and mosques in coastal areas should be built as two- or three-storeyed, reinforced structures, which could be designated explicitly as cyclone shelters. In addition, individuals affluent enough to build private *pukka* homes should be encouraged to include a second storey and reinforcements to permit their designated use as shelters.

In Bangladesh, the areas at risk of cyclone devastation are limited to the immediate coast and offshore islands. Communities in these areas should engage in preparedness exercises as part of Bangladesh's National Cyclone Warning Day. Locally organized drills could prepare the community to recognize warnings, consider responses, and identify the closest shelters.

The 1990s have been designated by the United Nations General Assembly as the International Decade for Natural Disaster Reduction.[c] The high death toll in the 1991 Bangladesh cyclone demonstrates the vulnerability of the coastal communities to cyclone-related mortality, despite an effective satellite warning system and a shelter programme. Renewed efforts to provide shelter, together with preparedness activities to educate the population to respond effectively, could have a major impact in decreasing cyclone-related mortality.

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Résumé

Facteurs de risque de mortalité lors du cyclone de 1991 au Bangladesh

En dépit du renforcement des mesures de lutte contre les catastrophes naturelles, les cyclones constituent toujours une grave menace pour les populations côtières du Bangladesh. A la suite du cyclone d'avril 1991, qui a causé la mort de 138 000 personnes dans le pays, une évaluation épidémiologique rapide a été entreprise pour déterminer les facteurs de risque de mortalité associés aux cyclones et pour définir des stratégies de prévention. Une enquête effectuée de façon non aléatoire sur 45 groupes d'habitations abritant 1123 personnes a montré que la mortalité était maximale chez les enfants de moins de dix ans (26%) et les femmes de plus de 40 ans (31%). Près de 22% des personnes qui n'ont pu se réfugier dans un bâtiment en béton ou en briques ont trouvé la mort, alors que toutes les personnes qui se trouvaient dans des bâtiments de ce type ont survécu. A l'avenir, la mortalité associée aux cyclones au Bangladesh pourrait être réduite par une information plus efficace de la population — ce qui lui permettrait de réagir plus rapidement — un meilleur accès aux abris anticycloniques et une meilleure préparation des com-

[c] *International Decade for Natural Disaster Reduction: report of the Secretary-General.* Unpublished UN document A/43/723.

munautés à haut risque. Les victimes parmi les femmes et les enfants de moins de dix ans, notamment, seraient moins nombreuses si les familles, les voisins, les autorités locales, et plus spécialement les responsables des systèmes d'alerte et des opérations d'évacuation, accordaient une attention spéciale à cette partie particulièrement vulnérable de la population.

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