Is Climate Change Breeding a Global Dengue Epidemic?

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Many climatologists and governments around the world have agreed that greenhouse gases released by means of human activities, such as industrialization or the use of environmentally unfriendly products, will alter the earth's climate. In particular, information drawn from climate models have led the Intergovernmental Panel on Climate Change (IPCC) to forecast an increase in world average temperatures of 1.4 – 5.8ºC by the year 2100. This phenomenon has been dubbed "global warming" by its proponents and critics alike. There are those who refuse to embrace the concept of a global average temperature on account that different regions of the Earth are characterized by different climates and geographical attributes to start with. Nevertheless, it is accepted in writing that an upward temperature trend in most parts of the world is in effect, which may eventually lead to extremes of climate variability through the El Nino phenomenon. While certain regions of the world would encounter intense precipitation and flooding due to the melting of the polar ice caps, others would meet with prolonged drought and warmer weather. These might lead to adverse effects on human health, agriculture and biodiversity.

At present, attention has been drawn to biologists who are adding a new dimension to the issue of global warming. The claims made entail the potential of climate change to lead to the reemergence of vector- borne diseases such as malaria and dengue fever, as well as water- borne diseases like cholera. In particular, the spotlight lies upon dengue fever, being the world's most important mosquito- borne viral disease. At present, 2.5 billion people in 100 countries are estimated to be at risk of this disease, with around 60 million cases occurring annually. Many biologists have fingered the blame at global warming for altering temperature ranges and rainfall distribution around the globe, allowing the *Aedes* mosquito vector to colonise formerly uninhabitable temperate regions and to transmit the dengue virus to previously unaffected populations. Other biologists, however, insist that climatic effects are small relative to other socioeconomic and topographical factors that contribute to this burgeoning problem. They claim that the relationship between climate, human behaviour and infectious diseases is complex to the extent that predictions made are hard to validate. However, both climate change and these other factors are most likely to complement each other, hence it ought to be inappropriate to pin all of the blame on the former.

This article seeks to assess the potential of climatologic and non-climatologic factors to cause dengue epidemics. It shall also highlight the urgent need to address the causes of global warming and to develop improved diagnostic methods and vaccines. More importantly, the ways in which governments, subject experts and the community may collaborate to bring about a heightened level of security through surveillance and vector control will also be discussed.

Dengue fever: Causes and effects

The microorganism causing dengue is an RNA virus belonging to the family *Flaviviridiae*, and is classified as an arbovirus (arthropod borne). Four distinct serotypes of the virus are known at present, namely DEN-1, DEN-2, DEN-3 and DEN-4. These are distinguished by the number of antigens they each possess, that is, characteristic molecular features that stimulate the appropriate immune response. Infection of a host by one serotype confers lifelong immunity only to that serotype, but not to others. If two or more viral serotypes infect the same host sequentially, the secondary infection would cause an antibody response that is different from that caused by the primary infection. Hyperendemicity, or the co-circulation of multiple virus serotypes in an area, would increase the probability of sequential infections and cause more severe reactions. The consequences of infection include dengue haemorrhagic fever and dengue shock syndrome (DHF/DSS), both characterized by fever and increased vascular permeability, with additional hypertension or an increased pulse pressure for the latter (Gubler and Kuno 1997).

The vectors responsible for the transmission of the dengue flavivirus from viremic to susceptible human beings have been established to be mosquitoes of the subgenus *Stegomyia*. The most significant of these would be *Aedes aegypti* and *Aedes albopictus*, among others. Researchers have noted that the vectors are well designed in nature, having observed their minute size in relation to their targets. In addition, it is also feasible to reason that the symptoms of DHF/DSS, though severe, are not sufficiently so to justify immediate evacuation of human hosts from the regions of transmission. This ensures a sustained supply of blood meals for the mosquito vector and provides the virus with opportunities for reproduction.

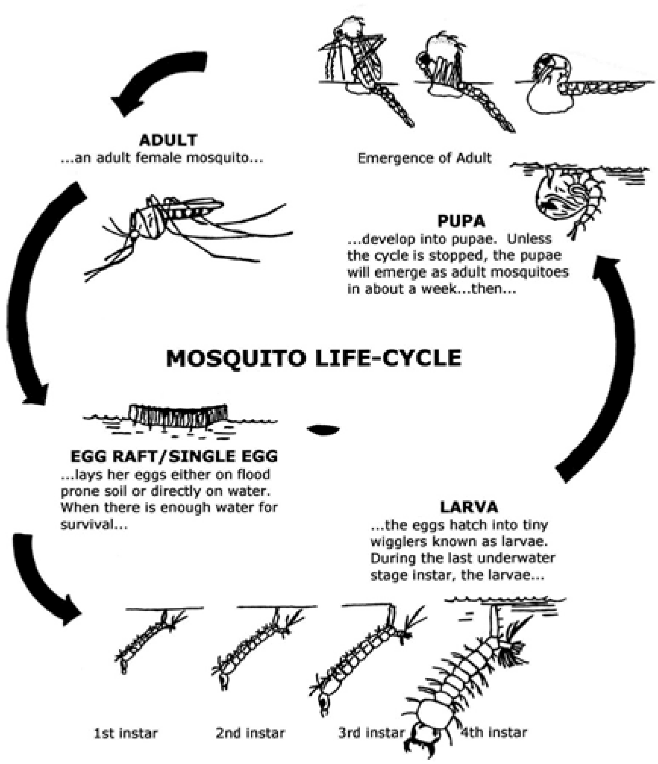


Figure 1: Overview of life cycle of mosquito vector
Source: www.wuvcd.org/mosquito/lifecycle.html

Analysis of the virus-vector relationship has shown that female *Aedes aegypti* vectors are capable of passing the virus by transovarian (vertical) transmission to their offspring. The eggs of the vector can remain viable for long periods of time despite cool and dry conditions. However, the vector itself is unable to survive cool temperatures, and hence its geographical distribution is currently confined to warmer latitudes and lower altitudes nearer to the equator. The survival rates of both virus and vector could be enhanced by climate changes such as global warming and the El Nino Southern Oscillation, a fact that warrants our attention.

Effects of altered climate variables on vector behaviour

According to observational studies, increases in environmental temperature due to global warming have displayed positive correlations with the range and spread of the mosquito vector. Mathematical models have demonstrated that between 1880 and 2050, winter temperatures in the northern hemisphere may rise by 1-4ºC on average, and up to 3ºC in the southern hemisphere. This could indicate a large shift of the 10ºC winter isotherm for Europe and North America, and southwards in the southern hemisphere (Houghton et al., 1995). In other words, the range of *A. aegypti* would be significantly increased to include previously uninhabitable temperate regions, along with the proportion of the human population at risk of outbreaks of dengue fever.

Apart from increases in the range of the *A. aegypti* vector, studies were conducted on the effects of temperature and relative humidity on the flight performance of female *A. aegypti* using flight distance, duration and speed as major parameters (Rowley and Graham 1968). It was found that sustained tethered flight occurred from 15 - 32ºC, with the optimal temperature being 21ºC. In general, flight temperature was greater below 27ºC. In contrast, a 30 – 90% range of relative humidities did not cause any influence on flight performance at constant temperature. Using these observations, it could be argued that rising temperatures due to global warming beyond 27ºC may not necessarily equate to increased range of distribution of the mosquito vector. Rather, extremes of temperature beyond the upper limit of 35ºC could adversely affect flight performance and hamper the vector's ability to venture into new habitats.

Climate change may also have effects on the life cycle of the mosquito vector. Eggs are laid individually by female *A. aegypti* on damp walls of artificial and natural water containers, and may resist dessication for several weeks to months. Global warming could bring about a rise in the frequency and intensity of the El Nino phenomenon, which causes more frequent storms, heavy rain, regional droughts and warm temperatures. Increasing precipitation is likely to increase the availability of oviposition sites which in turn could have a lengthening effect on the flight distance of female vectors (Reiter and others 1995). However, it is argued that torrential rainfall may wash away breeding sites, while droughts in wet areas could create pools of stagnant water suitable for oviposition. Hence, a rise in rainfall may not always be favourable to vector propagation.

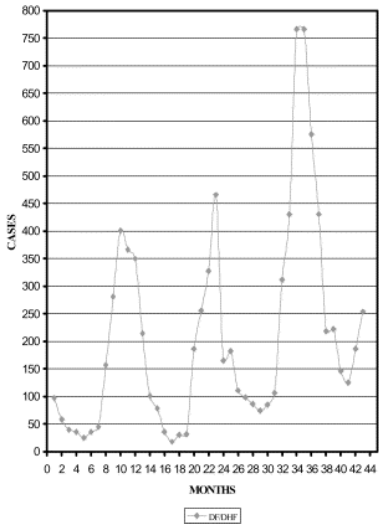
Research has shown that higher ambient temperatures reduce the size of larvae which leads to smaller adult mosquitoes. These in turn must feed on humans or other blood sources more frequently to obtain proteins needed for egg production (Jetten and Focks 1997). Hence, mosquitoes that require more than one blood meal per gonotrophic cycle lead to increased biting rates and hence an increased probability of dengue transmission. This could possibly suggest that global warming may precipitate the growth of a dengue epidemic in a relatively uninfected population so long as there exists contact between smaller vectors and newly introduced viremic individuals.

It may not be appropriate to associate global warming with increased levels of rainfall since the effects may vary in different regions of the world. Some researchers prefer to make assessments based on a third variable: relative humidity. Studies that utilized a moisturized membrane with humidity similar to that of human skin revealed that *A. aegypti* vectors were more effectively attracted to sources of moisture once they had been water starved (Khan and Maibach 1967). Hence, it is believed that a combination of high temperatures and relative humidity would facilitate mosquitoes in seeking target hosts and hence disease transmission.

Dependence of viral replication and transmission on climate change

Changes in temperature have been proven to increase rates of flavivirus replication within the mosquito vector, depending on the serotype, amount of virus ingested, and possibly the species of mosquito involved. Viral replication is limited to cells of the posterior midgut after the mosquito completes feeding on a viremic human host. The amount of time required for reproduction of the virus and its distribution to other parts of the insect is known as the extrinsic incubation period (EIP). Current research suggests that increases in the surrounding temperature may shorten the extrinsic incubation period in two ways. Firstly, the period of viral replication is reduced. Secondly, the time taken for the virus to travel to the mosquito's salivary glands and be present when the mosquito takes its next blood meal is also shortened. The net effect is to increase the number of infective transmissions during the adult stage of each virus- carrying mosquito. These observations may be well founded knowing that arthropods such as mosquitoes are cold blooded and hence their internal body temperatures correlate with those of the surroundings. Some researchers, though, have pointed out that constant laboratory temperatures may not be reflective of fluctuating temperatures in nature, making predictions on warming effects on viral behaviour less justifiable. Furthermore, research is often carried out using groups of mosquitoes rather than individual specimens (Gubler and Kuno 1997). This probably eliminates the spread of time measurements that would have been observed for individuals, but which leads to an apparent positive correlation between temperature and rates of transmission. Gubler, too, writes that "it is not known what percentage of infected insects was infectious".

Could all these observations lead simply to the conclusion that global warming will cause significant risk to the human population on account that scientific evidence tells us so? There are, for certain, major non-climatological factors which may contribute to increased dengue transmission rates. Furthermore, these may well have confounded statistical data obtained from population studies, leading critics to claim that there is hardly a need for humans to worry about a widespread dengue epidemic just because the environment is getting warmer and wetter. Figures 2, 3 and 4 (page 8) are graphs that summarize data obtained from an investigation of the dependence of dengue fever incidence on seasonal temperature fluctuations in Puerto Rico. Figures 2 and 3 reveal that upsurges in dengue cases coincided well with increases in temperature according to the seasons. In Figure 4, a regression plot of the number of dengue cases on temperature suggests a positive correlation between the two variables. However, the significant deviation of the number of cases from the average at higher temperatures provides evidence for suggesting the influence of non-temperature related factors such as rainfall or human activity on dengue incidence.



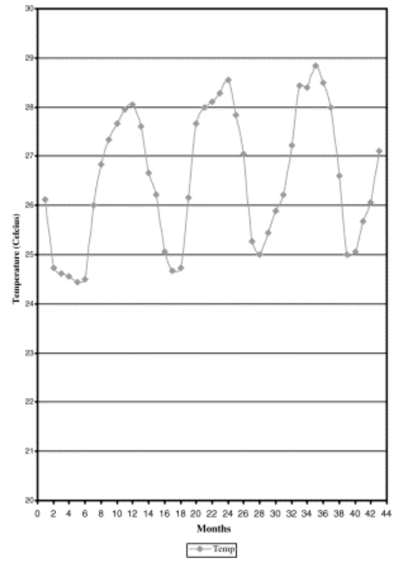


Figure 2 **Figure 3**

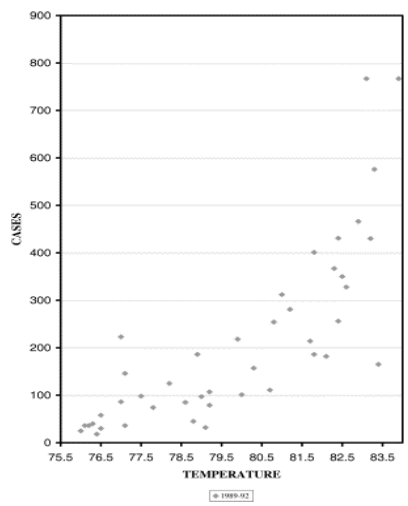


Figure 4

Fig. 2.: The monthly incidence of dengue fever and dengue hemorrhagic fever in Puerto Rico: January 1989–July 1992 (*Source*: Perez et al., 1994).

Fig. 3. The monthly mean temperature in Puerto Rico: October 1988–April 1992. *Note*: Humid tropical climate (*Source*: NCDC/NOAA).

Fig. 4. The monthly incidence of dengue plotted against temperature lagged 3 months for the years 1989–1992 in Puerto Rico.Source: An investigation into the cyclical incidence of dengue fever
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Joseph Keating

Human intervention: An impediment to global warming and its effects?

A review of the history of infectious diseases could explain why some are cautious about attributing surges in dengue incidence rates solely to global warming. Paul Reiter (1999) observed that in the early 1920s, 16.5 million people suffered from malaria at extreme northern latitudes such as the Arctic Circle. If rising temperatures and intensity of rainfall (in part due to the El Nino Southern Oscillation) are to blame for potential dengue epidemics, why have such outbreaks already surfaced in the past? Critics have already offered an easily understandable alternative explanation. The suggestion made is that non- climatologic factors like advances in medicine including immunization, improved housing and sanitation and government intervention discontinued the epidemics. Conversely, the absence of these conveniences in mainly developing countries could intensify the disease rates by acting in conjunction with global warming.

A major human factor which is associated with dengue transmission rates is the level of urbanization. According to United Nations reports, human migration will result in around 65% of the world's population living in cities by the year 2025. This would probably place heavy demands upon public health infrastructure as well as sanitation services. Alternatively, the introduction of viremic individuals carrying new dengue serotypes into a previously unaffected population could lead to a rise in transmission rates. Government intervention in the form of health screening and active vector eradication efforts could indirectly neutralize the adverse effects on dengue incidence rates brought about by climate change. As further evidence has indicated, there were more than 50000 cases of dengue in three Mexican states bordering the Rio Grande, and only 100 cases in Texas on the other side of the river from 1986-1990. The latter has been attributed to air- conditioning of homes and a working lifestyle, so that people were less likely to stay at home during the day where they would be bitten and infected. In general, the ability of the human population to respond to the proposed effects of climate change on infectious diseases has a hand in influencing patterns of disease spread.

The effects of topography may also account for the inaccuracy of predictions made on a global scale. Temperature and precipitation may vary within a country due to the diversity of geographical elevation. For example, high mountains and hills account for about 69% of Taiwan's land area while the remaining 31% consists of alluvial plains where human communities, farming activities and industries are concentrated. It could thus be deduced that the potential for epidemic outbreaks would be confined to lower altitudes where temperatures are relatively warmer. Moreover, oviposition sites in the form of artificial containers such as water storage barrels, flower pots and trash receptacles would be readily available, as would be a sustained reservoir of human hosts. In contrast, large- scale global models do not base their predictions upon such localized parameters and may thus over or under-exaggerate the estimates of human populations at risk. Interestingly, too, the impact of rainfall on adult vector density is not the same for all vector species (Focks and others 1993). *A. aegypti* is less susceptible to oral infection and hence acts as a selecting mechanism for viral strains causing high levels of viremia in humans. It is the main species responsible for promoting the epidemic form of the disease. However, *A. aegypti* prefers indoor habitats and would thus be less susceptible to changes in rainfall intensity as compared to *A. albopictus*, which has mostly outdoor larval habitats. Scientists who claim that increasing precipitation directly raises the chances of an epidemic dengue outbreak may have overlooked such a factor. For such reasons, global warming does not completely equate to a global rise in dengue transmission rates.

Solutions to curb global warming and prevent the spread of dengue

It is worth stressing that although socioeconomic and topographical factors may mitigate the effects of climate change on rates of dengue fever, the potential of global warming to inflict an epidemic outbreak should not be negated. In view of the aforementioned thought, governments around the world have chosen to adopt a published set of rules targeted at reduction of greenhouse gas emissions to curb global warming known as the Kyoto Protocol. Notably, the United States was the first of 160 participating nations to pull out, citing concern for its own economy. Countries around the world must understand that infectious diseases such as dengue can transcend international borders with rapid urbanization, travel and globalization. Hence, they must be open to discussion on feasible means to cope with this threat.

At the level of meteorological and medical research, more work must be done to take into account variations in social and ecological factors, as well as disease transmission patterns in making predictions. Only then will there be greater accuracy in making deductions from climate models when combined with easily acquired information on weather variability. Early diagnosis of patients with symptoms such as DHF/DSS is necessary to prevent loss of lives. In particular, detection of viruses in human sera in endemic areas is cumbersome due to the mildness of symptoms and their sporadic nature which may contribute to underreporting. Current equipment for viral isolation and detection must be used whenever appropriate, so as to facilitate the screening of human samples up to serotype level during large scale surveillance programmes. Meanwhile, the World Health Organisation is making development of vaccines a key priority, so as to boost the immunocompetency of human populations to multiple dengue serotypes. In addition, there is a need to monitor the use of live, attenuated vaccines which are weakened strains of the virus used to stimulate production of antibodies in individuals. There is a remote possibility that these could revert to a former virulent form by mutation. Genetic engineering is also being employed to create recombinant subunit vaccines for large scale commercial production.

The greatest challenge in dealing with dengue at the community level is human complacency. In Singapore, dengue outbreaks continue to occur even though vector density is extremely low due to a rigorous control programme (Gubler and Kuno 1997). This explains the need for public education campaigns on the symptoms, spread and prevention of dengue. Environmental manipulation such as improved delivery of water or proper storage of containers could greatly limit available sites for vector oviposition and thus breeding. Chemical methods such as fogging should be used sparingly, owing to the possibility of increasing mosquito resistance to the insecticide and adverse effects on human and aquatic organisms. Studies done in Thailand showed that fogging with malathion gave a 99% reduction in adult mosquitoes, only to have them return to pre-treatment levels within two weeks (Chua and others 2005). Biological control methods such as the use of fish, bacteria or water fleas to prey on or compete with mosquito larvae are mostly experimental, but nevertheless feasible. All in all, active surveillance must be observed through reporting suspected cases to the medical authorities. An early warning system through monitoring of temperature and precipitation rates one time lag before suspected epidemic outbreaks would also help brace the local health infrastructure for impact.

Conclusion

Climate change and socioeconomic factors function hand in hand in promoting dengue outbreaks, whether local or global. Many mechanisms by which climate variability may alter vector or viral behaviour and hence disease transmission have been well studied through intensive research. However, these do not strictly indicate that the global dengue epidemic will be consistently on the rise. The human species is one that can adapt through means of technology to ensure its survival. It is constantly bolstering its defenses through improving current knowledge of disease mechanisms, pathophysiology of viruses, and development of cures and vaccines. It is obvious that climate change cannot be allowed to regulate our vulnerability to such a disease.

As long as humans avoid being complacent and maintain their vigil through constant surveillance and education, action can be taken to offset the mechanisms brought about by climate change. However, these require initiative and collaboration on the part of governments, medical researchers, climatologists and the public. It is time to lift the blame on the weather, and assess our options for foiling a global dengue epidemic.

References

1.Gubler, D.J., Kuno,G. (1997). *Dengue and dengue hemorrhagic fever.* Wallingford, Oxon, UK ; New York : CAB International, pp. 1-88.

2. Kaplan, C. (1997). *Infection and environment.* Oxford ; Boston : Butterworth-Heinemann, pp. 117-121.

3. Lashley, F.R. & Durham, J.D. (2002). *Emerging infectious diseases : trends and issues.* New York : Springer Pub, pp. 103-111.

4. Brower, V. (2001, September 15). Vector-borne diseases and global warming: are both on an upward swing? *EMBO Rep.*, 2(9), 755-757

5. Campbell-Lendrum, D. & Reithinger, R. (2002, December 1). Dengue and climate change. *Trends in Parasitology*, 18(12), 524.

6. Chua, K.B., Chua, I.L., Chua, I.E. & Chua, K.H. (2005). Effects of chemical fogging on immature Aedes mosquitoes in natural field conditions. *Singapore Medical Journal*, 46(11), 639-644.

7. Hales, S., de Wet, N., Maindonald, J. & Woodward, A. (2002, September 14). Potential effect of population and climate changes on global distribution of dengue fever: an empirical model. *The Lancet*, 360(9336), 830-834.

8. Keating, J. (2001, December). An investigation into the cyclical incidence of dengue fever. *Social Science & Medicine*, 53(12), 1587-1597.

9. Khasnis, A.A. & Nettleman, M.D., (2005, November). Global Warming and Infectious Disease. *Archives of Medical Research*, 36(6), 689-696.

10. McCarthy, M. (2001, April 14). Uncertain impact of global warming on disease. *The Lancet*, 357(9263), 1183.

11. McMichael, A.J., Woodruff, R.E. & Hales, S. (2006, March 11). Climate change and human health: present and future risks. *The Lancet*, 367(9513), 859-869.

12. Patz, J.A. & Reisen W.K., (2001, April 1). Immunology, climate change and vector-borne diseases. *Trends in Immunology*, 22(4), 171-172.

13. Reiter,P. (1996, August 31). Global warming and mosquito-borne disease in USA. *The Lancet*, 348(9027), 622.

14. Rowley, W.A. & Graham, C.L. (1968, September). The effect of temperature and relative humidity on the flight performance of female Aedes aegypti. *Journal of Insect Physiology*, 14(9), 1251-1257.

15. Wu, P.C., Guo, H.R., Lung, S.C., Lin, C.Y. & Su, H.J. (2007, July). Weather as an effective predictor for occurrence of dengue fever in Taiwan. *Acta Tropica*, 103(1), 50-57.

16. Chow, V.T.K. The Challenges of dengue- Desperately Seeking Solutions. *Singapore Medical Journal*. Retrieved 26 September, 2007 from the World Wide Web: http://www.sma.org.sg/smj/3906/articles/3906ed2.html

17. Chaturvedi, U. C., Shrivastava, R. & Nagar, R. (2005, May). Dengue vaccines: Problems & prospects. *Indian Journal of Medical Research*. Retrieved 26 September, 2007 from the World Wide Web: http://findarticles.com/p/articles/mi_qa3867

18. Dengue Fever. *Wikipedia*. Retrieved 26 September, 2007 from the World Wide Web: http://en.wikipedia.org/wiki/Dengue_fever

19. Global warming. *Wikipedia*. Retrieved 26 September, 2007 from the World Wide Web:
http://en.wikipedia.org/wiki/Global_warming

20. Marshall, C. (2002). Global Warming: Implications on Public health. *Geological Resources and the Environment*. Retrieved 26 September, 2007 from the World Wide Web:
http://www.gsu.edu/~geohab/courses/geo12001/student%20papers/Public%20Health%20and%20Global%20Warming.doc

21. Mosquito Life Cycle. *West Umatilla Vector Control District*. Retrieved 26 September, 2007 from the World Wide Web:
http://www.wuvcd.org/mosquito/lifecycle.html

22. Samuel, P. P. & Tyagi, B. K. (2006, May). Diagnostic methods for detection & isolation of dengue viruses from vector mosquitoes. *Indian Journal of Medical Research*. Retrieved 26 September, 2007 from the World Wide Web:
http://findarticles.com/p/articles/mi_qa3867

23. Wegbreit, J. The Possible Effects of Temperature and Precipitation on Dengue Morbidity in Trinidad and Tobago: A Retrospective Longitudinal Study. Retrieved 26 September, 2007 from the World Wide Web:
http://www.umich.edu/~csfound/545/1997/weg/index.html