the more variable, shallower environments is higher than that of the species living in the deeper, supposedly more stable environments. Furthermore, the difference between species durations in shallow and deep water is far greater north of Cape Hatteras. Finally, some species are capable of living at all depths and the durations of these are similar to those of the deep water species. The data have not yet been analyzed to ascertain whether or not these species may have evolved in shallow water and then migrated to deeper water, or vice versa. Once evolved, however, these species enjoy a long duration.

Our data are difficult to compare with those obtained from work on mollusks (*11*) because of the different categories used (evidently, too few data exist on mollusk species living deeper than 200 m to estimate their species durations), but some comparisons can be made. The mollusks were divided into those species capable of living at depths of less than 1 m, and those living at greater depths, with a maximum of about 200 m. The more stenotopic deeper dwelling species are thought to have the higher rate of evolution. Species capable of living at less than 1 m (eurytopic) tolerate a wide variety of environmental conditions and are thought to be less prone to extinction and have a lower rate of evolution. The same onshore-offshore pattern was suggested for Phanerozoic shelf communities where major ecological innovations were believed to occur nearshore, but species turnover was considered higher offshore (*12*). This higher rate of evolution suggested for species living in environments with less variability is not the pattern we observe with benthic foraminifera. Instead, species restricted to the "harsher" environments have the shortest durations.

Our data indicate that the highest rate of evolution (and extinction) occurs in the more variable environments. As more data for other organisms become available perhaps their patterns of species turnover will become comparable. On the other hand, organisms may differ in their evolutionary patterns. This is certainly so when we consider the average species duration which, regardless of the environment, is two to three times longer for benthic foraminifera than for mollusks.

MARTIN A. BUZAS
Department of Paleobiology,
Smithsonian Institution,
Washington, D.C. 20560
STEPHEN J. CULVER
Department of Geological Sciences,
Old Dominion University,
Norfolk, Virginia 23508

References and Notes

1. S. M. Stanley, *Macroevolution* (Freeman, San Francisco, 1979).
2. W. R. Walton, in *Approaches to Paleoecology*, J. Imbrie and N. Newell, Eds. (Wiley, New York, 1964), pp. 151–237; T. G. Gibson and M. A. Buzas, *Geol. Soc. Am. Bull.* **84**, 217 (1973); B. W. Hayward and M. A. Buzas, *Smithson. Contrib. Paleobiol.* **36**, 1 (1979).
3. R. Douglas and F. Woodruff, in *The Oceanic Lithosphere*, C. Emiliani, Ed. (Wiley, New York, 1981), vol. 7, pp. 1233–1327.
4. S. J. Culver and M. A. Buzas, *Smithson. Contrib. Mar. Sci.* **6**, 1 (1980); M. A. Buzas and S. J. Culver, *Science* **209**, 687 (1980); S. J. Culver and M. A. Buzas, *J. Foraminiferal Res.* **11**, 217 (1981).
5. M. A. Buzas, C. F. Koch, S. J. Culver, N. F. Sohl, *Paleobiology* **8**, 143 (1982).
6. Specimens were examined in the following museums: Sedgwick Museum, Cambridge; Natur-Museum Senckenberg, Frankfurt; Rijks Geologische Dienst, Haarlem; Institut voor Aardwetenschappen, Leuven; British Museum (Natural History), London; The Manchester Museum, Manchester; Institut für Paläontologie und historische Geologie, Munich; Institut für Paläontologie, Munich; Staatliches Museum für Naturkunde, Stuttgart; Institut und Museum für Geologie und Paläontologie, Tubingen; Naturhistorisches Museum, Vienna; Institut für Paläontologie der Universität, Vienna; and Museum of Natural History, Washington, D.C.
7. R. V. Dietrich, J. T. Dutro, R. M. Foose, in *AGI Data Sheet 1* (American Geophysical Institute, Falls Church, Va., 1982).
8. J. J. Sepkoski, Jr., *Paleobiology* **4**, 343 (1975).
9. F. L. Parker, *J. Paleontol.* **38**, 617 (1964).
10. The number of localities in deeper water south of Cape Hatteras is too low to permit with assurance the same division in deeper water. Cape Hatteras does, however, delimit a boundary for both shallow (shelf) and deeper (slope) water species (*4*).
11. J. B. C. Jackson, *Am. Nat.* **108**, 541 (1974); D. Jablonski and J. W. Valentine, in *Evolution Today*, G. G. E. Scudder and J. L. Reveal, Eds. (Carnegie-Mellon University, Pittsburgh, 1981), p. 441–453.
12. D. Jablonski, J. J. Sepkoski, Jr., D. J. Bottjer, P. M. Sheehan, *Science* **222**, 1123 (1983).
13. We thank F. Rögl, H. Hagn, M. Urlichs, H. Malz, H. Hooyberghs, A. Liebart, H. Gocht, J. Hohenegger, W. Piller, J. W. Chr. Doppert, M. V. Hounsome, H. B. Whittington, M. Dorling, C. G. Adams, R. L. Hodgkinson, K. Towe, D. Culver, R. K. Smith-Evernden, L. Ward, G. Jones, T. Cronin, J. B. Saunders, and L. Collins for their help. Supported by a Smithsonian Scholarly Studies Grant and NSF grant EAR82-16550.

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Ionospheric Sporadic-E Parameters: Long-Term Trends

Abstract. *The results of observations over 3½ solar cycles of ionosonde parameters describing sporadic-E patches (E_s) are given for two Southern Hemisphere stations. Analysis has revealed systematic changes in the occurrence probabilities of f_oE_s and f_bE_s, changes that are independent of time of day or season. It is unlikely that observational effects can be entirely responsible for the trends, which suggest that major long-term changes may be occurring at E region heights.*

The ionospheric E region, produced by the photoionization of O_2 by solar continuum, Lyman β, and electron precipitation, extends from 100 to 130 km and contains plasma irregularities of various scales. One manifestation of the irregular nature of the region is the presence of localized patches of enhanced ionization some 300 km in horizontal scale and 1 to 3 km in vertical extent which occur in quasi-random fashion within the normal E region and have individual lifetimes of about 1.5 hours. These sporadic-E patches (E_s) are formed by the action of tides in the neutral atmosphere, bringing about the compression of electrons and positive metallic meteoric ions into thin sheets (*1*). The action of tidal winds is modified by internal gravity waves and turbulence, producing the essentially sporadic feature of this enhanced ionization. The morphology of E_s, the mechanisms controlling its formation, and its aeronomy are not well understood.

An international network of vertical swept-frequency radars (ionosondes) has been operating for decades, providing ionospheric data. The published hourly values of E_s parameters available from scaled ionograms are the ordinary wave-top penetration frequency (f_oE_s) and the highest frequency for which blanketing occurs for layers at greater altitudes (f_bE_s). In order to understand the aeronomy of E_s, it is necessary to relate the E_s parameters to identifiable properties of E_s patches. Although such relations are not clearly defined, it is known that f_bE_s is a measure of the ambient ionization density in an E_s cloud whereas f_oE_s is thought to be determined by the density of ionization irregularities within a cloud. Although hourly sampling at one ionosonde cannot yield detailed information about individual clouds, a long series of such ionosonde data is valuable in providing information on overall temporal characteristics. Thus, it is well known that temperate-latitude E_s is a daytime summer phenomenon (*2*) with daytime f_bE_s showing an in-phase solar cycle correlation (*3*).

Since reports of long sequences of E_s data are sparse, it is of interest to note that the New Zealand Department of Scientific and Industrial Research has provided scaled E_s parameters since 1947 for its network of ionosonde stations in the South Pacific. In an effort to determine the long-term characteristics of E_s occurrence, I have examined f_oE_s and f_bE_s values for two stations: Rarotonga (21.2°S, 200.3°E) in the subtropical region and Christchurch (43.5°S, 172.5°E) in the temperate zone. The mean monthly occurrence probabilities, *P*, were determined for three separate diurnal periods: 0000 to 0400 local mean time (morning), 1000 to 1400 (daytime), and 1900 to 2300 (evening). The limiting ionosonde frequencies used were as follows: for morning and evening, $f_oE_s \geqslant 4$ MHz and $f_bE_s \geqslant 2$ MHz, and for daytime, $f_oE_s \geqslant 5$ MHz and $f_bE_s \geqslant 4$ MHz. These limiting frequencies were chosen to provide a well-defined signature representing temporal changes in E_s occurrence while avoiding contamination by the normal E region at times when f_oE is high. The monthly P value (in percentages) for each data set was based on 150 (or 155) values, therefore providing a low sampling error. No distinction was made among the various types of E_s defined by the appearance of ionosonde traces except that the auroral type was excluded. The results presented here are for January 1948 to April 1980 for Rarotonga (when the station closed) and January 1947 to December 1983 for Christchurch and as such form, as far as I know, the longest analyzed E_s series to appear in the literature.

Figures 1 and 2 show the occurrence probabilities (12-month running mean smoothing was used to remove the strong seasonal cycle). Three features are evident in the plots: (i) large fluctuations occur, which are more marked than in other parameters of the ionospheric E and F regions; (ii) the daytime f_bE_s occurrence shows strong solar cycle control; and (iii) except for f_bE_s data in the daytime, the data for the two stations exhibit no coherent pattern. In addition, marked trends are present in the data, with f_oE_s decreasing with time and f_bE_s increasing. For example, the values of $P(f_oE_s)$ for Christchurch morning decrease from >30 percent in the late 1940's to <8 percent in the early 1980's. The trends occur for all diurnal periods and for both stations. The effect was also found to be present in all seasons. Figures 3 and 4 show the Rarotonga data with seasons isolated; the summer values are given by the mean of December and January, autumn by the mean of March and April, winter by the mean of June and July, and spring by the mean of September and October. To provide quantitative results, linear regressions were applied to the 12 plots of Figs. 1 and 2 to give the factors by which $P(fE_s)$ changed over the period: 37 years for Christchurch and 33.3 years for Rarotonga.

It is possible to express the change in the percentage occurrence in terms of an equivalent change in the limiting frequency adopted for analysis. Examination of published f_oE_s and f_bE_s data for the two stations yielded cumulative probability versus f_oE_s or f_bE_s values and hence gradients near the adopted limiting frequencies, thus permitting equivalent changes Δf (in megahertz) to be estimated. Thus, in Table 1 $\Delta f = +2.6$ MHz means that in order to explain the falling f_oE_s occurrence a shift in limiting frequency from 5.0 to 7.6 MHz would be required. The trends in the data occurring for both Southern Hemisphere stations, at all times of day and for all seasons, are substantial. If real, these trends represent gross changes, for example, in the ionization production or redistribution or in the characteristics of the plasma irregularities within E_s clouds.

Examination of the monthly means of the median values of f_oE for 10 to 14 hours for both stations over the three decades showed that the 12-month running means exhibited the expected close solar control. Although fluctuations of up to 0.3 MHz in f_oE for times at the same phase in the solar cycle were present, no trends in f_oE exist over the data period. In addition, the influx of meteoric material deduced from visual observations (*4*) and radar meteor data (*5*) also show no long-term systematic changes.

One possible source for the data trends is an observational effect involving the ionosonde technique itself. If changes in the ionosonde calibration or sensitivity have occurred over three decades, such changes clearly have impor-

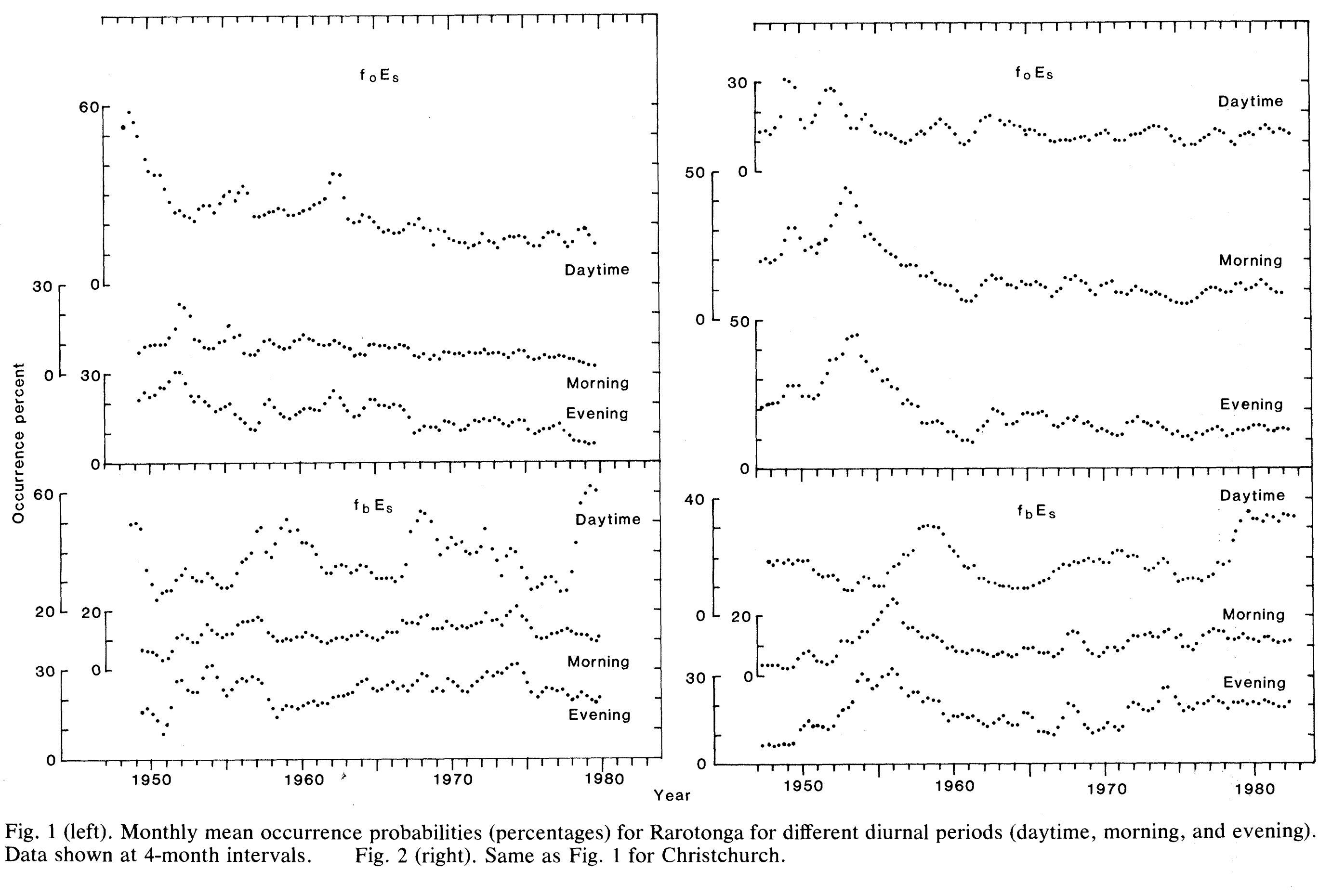


Fig. 1 (left). Monthly mean occurrence probabilities (percentages) for Rarotonga for different diurnal periods (daytime, morning, and evening). Data shown at 4-month intervals. Fig. 2 (right). Same as Fig. 1 for Christchurch.

Table 1. The changes in $P(f_oE_s)$ and $P(f_bE_s)$ at Rarotonga (RA) and Christchurch (CH), the uncertainties (u) in the factor, and the equivalent change in limiting frequency, Δf.

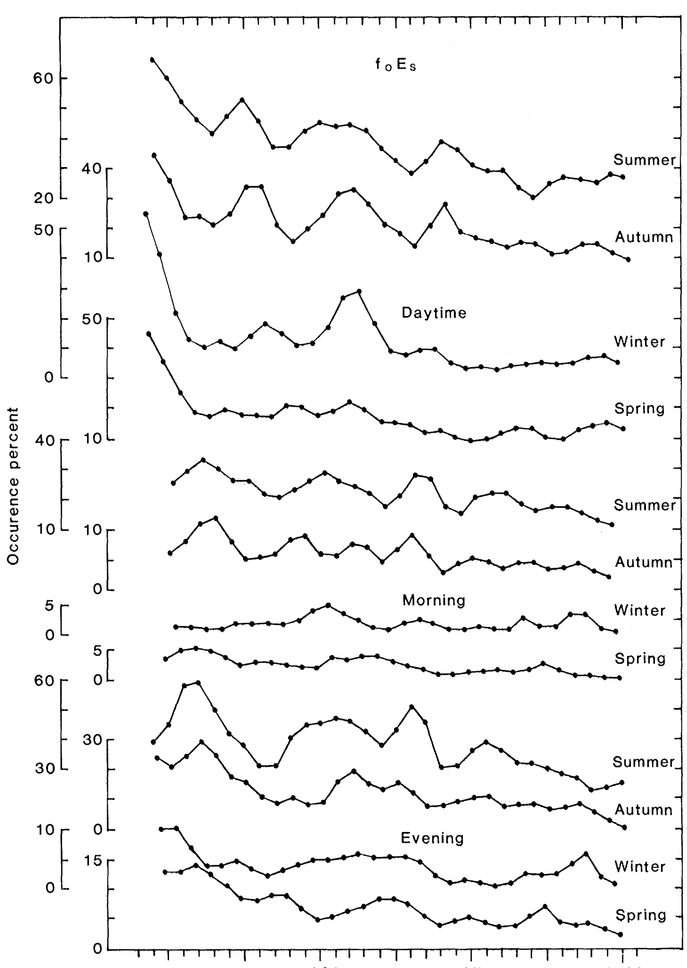
Parameter	Morning			Daytime			Evening		
	Factor	u (%)	Δf (MHz)	Factor	u (%)	Δf (MHz)	Factor	u (%)	Δf (MHz)
$P(f_oE_s)$ CH	0.15	5	+2.6	0.55	8	+0.6	0.3	3	+1.6
$P(f_bE_s)$ CH	1.46	18	−0.5	1.67	12	−0.5	1.29	19	−0.3
$P(f_oE_s)$ RA	0.76	32	+0.4	0.59	42	+0.5	0.39	30	+1.3
$P(f_bE_s)$ RA	1.54	9	−0.6	1.19	22	−0.2	1.23	13	−0.3

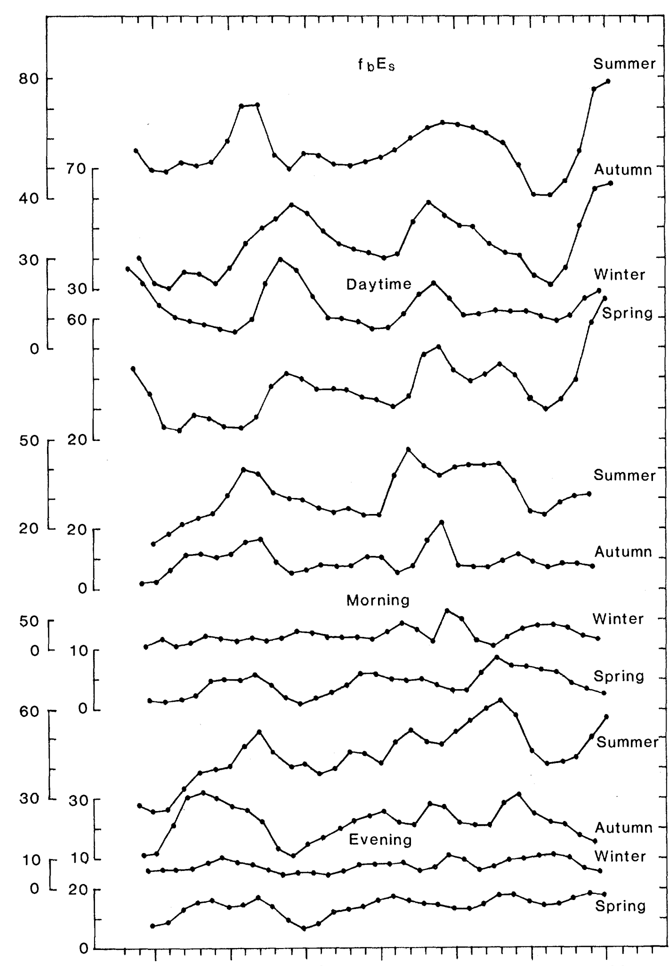
tant implications for ionospheric studies. However, it is difficult to relate the observed trends to the operation of ionosondes. In seeking a source for systematic changes in E_s parameters, we must consider four aspects of the observational technique: ionosonde scaling procedures, equipment changes, environmental noise changes, and broadcast interference.

Scaling rules for E_s have been long established, and their use has been continuously monitored by international agreement (*6*). The scaling has been carried out by the same institution over the period; early ionograms have been recently rescaled, and the results found consistent with the early values (*7*). In addition, the scaling has been carried out by the same operator since 1972 (*7*).

The only significant changes to ionosonde equipment were the replacement of ionosonde type at both stations in July 1956 and a change of recording film type in July 1969. No associated discontinuities are apparent in any of the data sets. In fact, scaled E_s parameters are rather insensitive to ionosonde gain. Programmed receiver gain changes at each hourly operation were a feature of soundings with ±10-dB changes from the normal operating level producing no measurable change in f_oE_s and f_bE_s values (*7*). The dominant E_s type during daytime at both stations is cusp. Since a cusp-type layer has a clearly defined top frequency so that signal strength is fairly constant as a function of ionosonde frequency up to a sharp cutoff, f_oE_s is unlikely to be gain-sensitive.

The major contribution to environmental noise, composed of atmospheric, galactic, and man-made noise, would be integrated local-level, man-made sources that are dependent on urban settlement densities. As urban population densities increase, so deterioration in the signal-to-noise ratio at nearby ionosondes would be expected. However, the fact that both stations are well removed from large population centers contrasts with the situation in many parts of the globe where urban development has been marked over the three decades. Man-made noise follows a diurnal variation with an early-morning minimum. If the observed trends were a direct consequence of changes in the signal-to-noise ratio, less change would be expected at night: in fact the opposite is often found.





Year

Fig. 3 (left). Occurrence probabilities (f_oE_s) for Rarotonga for different seasons and diurnal periods. Fig. 4 (right). Same as Fig. 3 (f_bE_s).

Moreover, noise would be expected to affect f_bE_s only at the lowest observed f_bE_s value (that is, in proximity to f_oE) so that an effect would be noticeable only in summer daytime near sunspot maximum.

Broadcast interference is minor at both these South Pacific stations. A survey (*7*) of records to establish whether scaled values were affected by interference (values designated ES), based on a comparison of data at times of high and low f_bE_s, revealed that interference did not measurably influence f_bE_s estimates. The ionogram parameter f_{min}, scaled from the lowest frequency reflection from the ionosphere, is interference-limited at night at both stations. An examination of f_{min} data for morning and evening periods shows that since 1957 (when published values commence) there have been no increases in the mean f_{min} with almost constant values of 1.0 MHz for Rarotonga and 1.5 MHz for Christchurch. In addition, there have been no trends in daytime (1000 to 1400) winter values with the mean monthly f_{min} fluctuating in the range 1.18 to 2.00 MHz for Rarotonga and 1.36 to 2.20 MHz for Christchurch.

In summary, it is difficult to relate the observed marked trends in f_oE_s and f_bE_s parameters to any known changes in ionosonde or observing conditions. The identification of any such changes would have important consequences for long-term ionospheric studies based on the use of ionosondes. Alternatively, an ionospheric mechanism might be sought in terms of, for example, a temperature structure changing over many years reflected in changes in tidal wind characteristics and hence in E_s formation. It is clearly important to establish whether the trends reported here are a feature of Northern Hemisphere stations.

W. J. BAGGALEY

Department of Physics,
University of Canterbury,
Christchurch, New Zealand

References and Notes

1. J. D. Whitehead, *J. Atmos. Terr. Phys.* **36**, 861 (1961).
2. ______, *Rev. Geophys. Space Phys.* **8**, 65 (1970).
3. C. A. Reddy and S. Matsushita, *J. Geophys. Res.* **73**, 1641 (1968); W. J. Baggaley, *ibid.* **76**, 4674 (1971).
4. V. Bumba, *Bull. Astron. Inst. Czech.* **6**, 141 (1955).
5. C. D. Ellyett, *J. Geophys. Res.* **82**, 1455 (1977); B. A. Lindblad, *Nature (London)* **273**, 732 (1978).
6. *Handbook of Ionogram Interpretation and Reduction* (International Union of Radio Science, Paris, ed. 2, 1972).
7. A. Stanbury, *Survey of Ionosonde Sensitivity and Calibration* (Geophysical Observatory, Department of Scientific and Industrial Research, Christchurch, New Zealand, 1983); personal communication.

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Animal-to-Man Transmission of Antimicrobial-Resistant *Salmonella:* Investigations of U.S. Outbreaks, 1971–1983

Abstract. *The importance and origin of antimicrobial-resistant* Salmonella *infections were examined in 52 outbreaks investigated by the Centers for Disease Control between 1971 and 1983. The case fatality rate was higher for patients infected with antimicrobial-resistant* Salmonella *(4.2 percent) than for those with antimicrobial-sensitive infections (0.2 percent). In the 38 outbreaks with identified sources, food animals were the source of 11 (69 percent) of 16 resistant and 6 (46 percent) of 13 sensitive outbreak strains.*

Antimicrobial-resistant *Salmonella* have accounted for a steadily increasing proportion of human *Salmonella* infections and now represent approximately 20 to 30 percent of salmonellae isolated from humans (*1, 2*). The importance of antimicrobial resistance in *Salmonella* has been questioned because most *Salmonella* infections do not require antimicrobial therapy. In addition, it has been suggested that antimicrobial-resistant *Salmonella* may be less virulent than antimicrobial-sensitive strains (*2–4*). The source of these resistant bacteria is also controversial. Some have argued that the administration of antimicrobials to animals—this use accounts for about half the antimicrobials produced yearly in the United States—selects for antimicrobial-resistant bacteria, has increased their prevalence in the food chain, and has been the principal cause of the increased incidence of drug-resistant strains in humans. However, others have argued that multiple-drug-resistant bacteria derive mainly from too frequent prescribing of antimicrobials for humans, particularly in hospitals, and that the human and animal pools of antimicrobial-resistant *Salmonella* overlap infrequently and transiently (*5, 6*).

The major obstacle to determining whether antimicrobial-resistant bacteria often arise from food-animal sources and present an important threat to human health has been the difficulty in tracing all the postulated steps from farm practice to human disease. Individual events in the complicated sequence have been documented, such as the selection for and persistence of resistant bacteria in food-producing animals resulting from the use of subtherapeutic doses of antimicrobials (*7–11*), the frequent presence of resistant *Salmonella* in products of animal origin (*12, 13*), the transmission of resistant microorganisms to humans (*6, 14*), and human disease resulting from multiply resistant bacteria (*1*). However, outlining all these steps in a sequence is rarely possible and does not indicate the relative frequency with which resistant bacteria arise from animal and human populations (*15*).

It may not be possible to determine exactly how often animal-to-man transmission of resistant enteric pathogens occurs (*16, 17*). However, it is possible to determine whether animal-to-man transmission of antimicrobial-resistant *Salmonella* has been demonstrated in an important fraction of *Salmonella* outbreaks investigated in the United States. We reviewed epidemiologic and laboratory data of all Centers for Disease Control (CDC) investigations of nontyphoidal *Salmonella* outbreaks between January 1971 and December 1983.

Summary reports were available and complete for 52 of 55 *Salmonella* outbreaks investigated by CDC personnel in the 12-year period. We could classify these outbreaks into three groups: (i) 34 that had occurred in the community; (ii) 12 that had occurred wholly within a hospital or institution; and (iii) 6 that had occurred both in the community and in a hospital (Table 1).

In only 5 of the 52 outbreaks was the antimicrobial susceptibility of the epidemic strain known at the time that the CDC was requested by state health departments to participate in these investigations. At the outset of CDC investigations, sources or modes of spread of outbreak strains were suspected in 11 of the 18 outbreaks traced to animals, in 9 of the 11 outbreaks originating from a common source, in 3 of the 4 outbreaks of another source, in 3 of the 5 outbreaks spread person-to-person in hospitals, and in 5 of the 13 outbreaks in which the source could not finally be determined.

Seventeen of the 52 outbreaks involved antimicrobial-resistant organisms and affected 312 persons, 13 of whom (4.2 percent) died from salmonellosis. Eight deaths in elderly persons were from community-acquired organisms in three outbreaks traced to raw milk and beef obtained from specific dairies and a beef herd (*18, 19*); the 5 deaths in 18 affected infants occurred in a single hospital nursery outbreak caused by multiply resistant *S. typhimurium* of unknown source. In contrast to fatalities caused by antimicrobial-resistant organisms, the 19 outbreaks caused by antimicrobial-sensi-