Fire Research Note No. 893

AN ASSOCIATION BETWEEN FIRE SPREAD
AND CASUALTIES IN FIRE

by

M. A. NORTH AND R. BALDWIN

October 1971

FIRE
RESEARCH
STATION

Fire Research Station,
Borehamwood,
Herts.
Tel. 01-953 6177

F. R. Note No. 893
October 1971

AN ASSOCIATION BETWEEN FIRE SPREAD AND CASUALTIES IN FIRE

by

M A North and R Baldwin

SUMMARY

Fire statistics for multi-storey houses indicate a possible association between the incidence of fires causing casualties and fire spread, even allowing for the presumed state of awareness of the victims at the time of the fire. This association is quite strong for fires involving fatalities and seems to indicate a strong correlation between fatalities and spread, but the association is relatively weak for fires involving non-fatal casualties, whose frequency appears to be correlated more with the frequency of outbreaks of fire.

It is pointed out that no causal relationship has been established and that there is more than one explanation for this association.

KEY WORDS: Fire statistics, fatalities, casualties, fire spread.

DEPARTMENT OF THE ENVIRONMENT AND FIRE OFFICES' COMMITTEE
JOINT FIRE RESEARCH ORGANIZATION

F. R. Note No. 893
October 1971

AN ASSOCIATION BETWEEN FIRE SPREAD AND CASUALTIES IN FIRE

by

M A North and R Baldwin

1. INTRODUCTION

Legislation for the control of fire safety in buildings is concerned with the prevention of life loss by inhibiting the spread of fire by compartmentation, control of linings, etc and by providing adequate means of escape. However, in dwellings, fire compartmentation exists only between one dwelling and another, and most casualties occur in the dwelling (or fire compartment) in which the fire originated. It is of considerable interest therefore to investigate what reduction in life loss would ensue if the size of fires was reduced, for example, by a policy of shutting doors, control of linings and combustible contents, etc. In this note a start is made to this problem by examining brigade fire reports for possible associations between the incidence of casualties and fire spread.

2. ASSOCIATION

Before setting out the data and the details of the analysis it is necessary to comment on the meaning of the term 'association' in a statistical sense, and on a measure of the intensity of association. Consider a population classified according to whether each member bears or does not bear an attribute A. The presence of the attribute we may denote by A, and the absence by $\bar{A}$. Suppose now the population classified according to two attributes A and B. Then A and B are positively associated if A occurs more frequently among the B's than among the $\bar{B}$'s, and negatively associated if not. In the context of the present paper, fatalities and fire spread are positively associated if fatalities occur more frequently among fires which do spread than among those that do not.

Consider the following table classifying a population by the two attributes A and B.

	B	$\bar{B}$
A	a	b
$\bar{A}$	c	d

Then Yule[1,2] has defined the coefficient of association, Q, by the equation

$$Q = \frac{ad-bc}{ad+bc}$$

If $Q = 0$, the attributes are independent, if $Q = 1$ there is complete (positive) association, and if $Q = -1$ there is complete negative association i.e., dissociation. This coefficient is a useful measure of the intensity of association between variables. For a more complete discussion, see Kendall[3].

3. DATA

The reports of fires in multi-storey houses attended by fire brigades during 1967 are examined for association between casualties and fire spread. Fires which started in common service spaces, roof spaces, etc. or which spread beyond the building of origin are excluded, since these could not be fitted successfully into our measure of fire spread. Fires in which clothing on a person was the material first ignited are also excluded, since the most minor fire in this class will probably cause a casualty and the casualty rate is in no way dependent on building standards. These clothing fires account for some 30 per centof fatal casualty fires and for about 10 per cent of non-fatal casualty fires in multi-storey houses.

For the purposes of this paper, we recognize two conditions of fire spread, which are defined as:

i) Spread (denoted 'S'). Fires which spread beyond the room of origin but were confined to the building of origin.

ii) Not-spread (denoted '$\bar{S}$'). Fires which spread beyond the item first ignited but were confined to the room of origin. Fires confined to the item ignited first are excluded because statistical studies have shown that it is not a reliable measure of size, depending more on the propensity of the public to call the brigade to a small out-break.

The fires are divided into three classes according to the casualties occurring in them. These are:

i) Fatal fires (denoted 'F'). Fires causing one or more fatal casualties.

ii) Casualty fires (denoted 'C'). Fires causing one or more non-fatal casualties, but excluding any fires with fatal casualties.

iii) Non-casualty fires (denoted '$\bar{C}$'). Fires causing neither fatal nor non-fatal casualties.

The chance of a person becoming a fire casualty must depend, to some extent, on his state of awareness at the time of the fire; on intuitive grounds, one would expect greater risk during the hours of night, when the majority of people are asleep. This factor also affects the chance of spread, through variations in the rate of discovery[4]. For this reason, the fires are further sub-divided into fires occurring during the day and those occurring during the night. The time of call to the fire brigade (excluding late calls) is taken as the time of occurrence of the fire, as it gives a first approximation to the time of origin of the fire. The definitions are:

i) Day (denoted 'D'). The time of call was 1100 hours through 1959 hours.

ii) Night (denoted '$\bar{D}$'). The time of call was midnight through 0759 hours.

The basic data used are shown in Table 1.

TABLE 1

Basic data for the analysis

		F	C	$\bar{C}$	Total
D	S	25	110	1,266	1,401
	$\bar{S}$	51	560	9,389	10,000
$\bar{D}$	S	35	62	363	460
	$\bar{S}$	40	123	1,779	1,942
Total		151	855	12,797	13,803

4. ANALYSIS

4.1. Casualty fires, spread and time of day.

We define the probability of a fire being a casualty fire, Pc, as follows:

$$Pc = \frac{C}{C + \bar{C}}$$

using the notation given above. A similar statistic (P_F) can be calculated for fatal fires. The casualty data from Table 1 are expressed as proportions in Table 2, where values of the coefficient of association, Q, are also given.

TABLE 2

Probability (Pc) of a casualty fire, broken down by fire spread and time of day

	D	$\bar{D}$	Q
S	0.080	0.146	- 0.33
$\bar{S}$	0.056	0.065	- 0.07
Q	0.19	0.42	-

As might be expected, there is greater probability of a casualty fire at night than in the day, both among the S's and the $\overline{S}$'s. Hence, there is negative association between casualties and day (equivalent to positive association between casualties and night), confirmed by the negative value of Q. Theprobability of a casualty fire is greater for fires which spread than for those which do not, both among the D's and the $\overline{D}$'s. This demonstrates a positive association between casualties and spread, confirmed by the positive value of Q.

4.2. Fatal fires, spread and time of day.

The data for fatal fires from Table 1 are expressed as proportions in Table 3, in which

$$p_F = \frac{F}{F + C + \overline{C}}$$

TABLE 3

Probability (p_F) of a fatal fire, broken down by fire spread and time of day

	D	$\overline{D}$	Q
S	0.018	0.076	- 0.64
$\overline{S}$	0.005	0.021	- 0.61
Q	0.56	0.59	-

This indicates that similar conclusions can be drawn for fatal fires as have been made for casualty fires. The degree of association is stronger for fatal fires than for those with casualties.

5. DISCUSSION AND CONCLUSIONS

An association was found between fatal and casualty fires in multi-storey houses and time of day, allowing for fire spread,and between fatal and casualty fires and fire spread, allowing for the state of awareness of the occupants.Hence even allowing for the expected association between casualties and state of awareness, there is still a residual association between casualties and spread.

The differences in the probability of a casualty fire with time of day and spread are small, except for spreading fires at night. The very small value of the coefficient of association between casualty fires (C) and not-spread ($\overline{S}$) means that this association can be ignored for most purposes. This is indicated by Fig. 1 which compares the number of casualty fires with the total number of fires through the day. The fire frequencies have been standardized and smoothed by the use of a 3-hour moving average. It can be seen that the frequency of casualty fires is chiefly dependent on the frequency of fires at any time.

The association between fatal fires, spread and time of day is much stronger than that for casualty fires; in fact the highest value of p_F (= 0.076) is an order of magnitude greater than the lowest (= 0.005). It appears that the probability of a fatal fire is higher by a factor of about three in fires which do spread than in those which do not, whether day or night fires are considered. This is shown in Fig. 2 as a clear correlation between spread and fatalities. The data of Fig. 2 were smoothed by the use of a moving average over the longer period of 5-hours because of greater random fluctuations in the data due to the fewer available data.

In spite of the clear associations discussed in this paper, care must be exercised in their interpretation. An association between two attributes does not establish a causal relationship between them. An association between F and S is also an association between S and F; that is, the chance of spread is higher in fatal fires than in not-fatal ones. It is impossible to say, at the moment, whether fire spread causes fatalities or fatalities lead to fire spread for example by killing the person(s) who would have discovered the fire.

REFERENCES

1. YULE, G. U. On the association of attributes in statistics. Phil. Trans. A, 194, 257 (1900).
2. YULE, G. U. On the methods of measuring the association between two attributes. J. Roy. Statist. Soc., 75, 579 (1912).
3. KENDALL, M. G. The advanced theory of statistics. Vol. 1. London (1947).
4. BALDWIN, R. A statistical approach to the spread of fire in buildings. Proceedings of C.I.B. symposium on the safety of structures in fire, Paris, 1971.

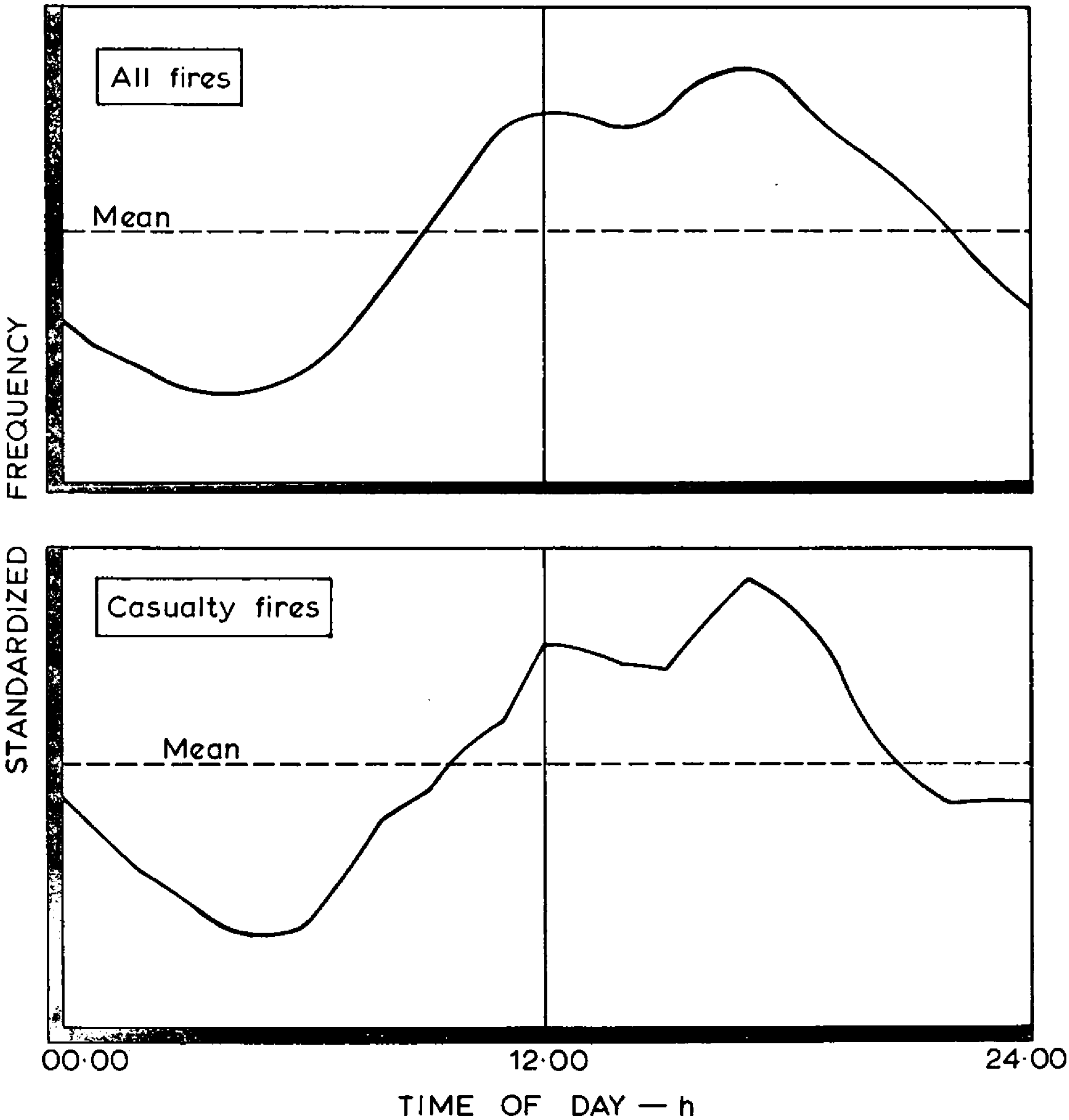

FIG. 1. DISTRIBUTION OF FIRES BY TIME OF DAY (SMOOTHED AND STANDARDIZED FREQUENCIES)

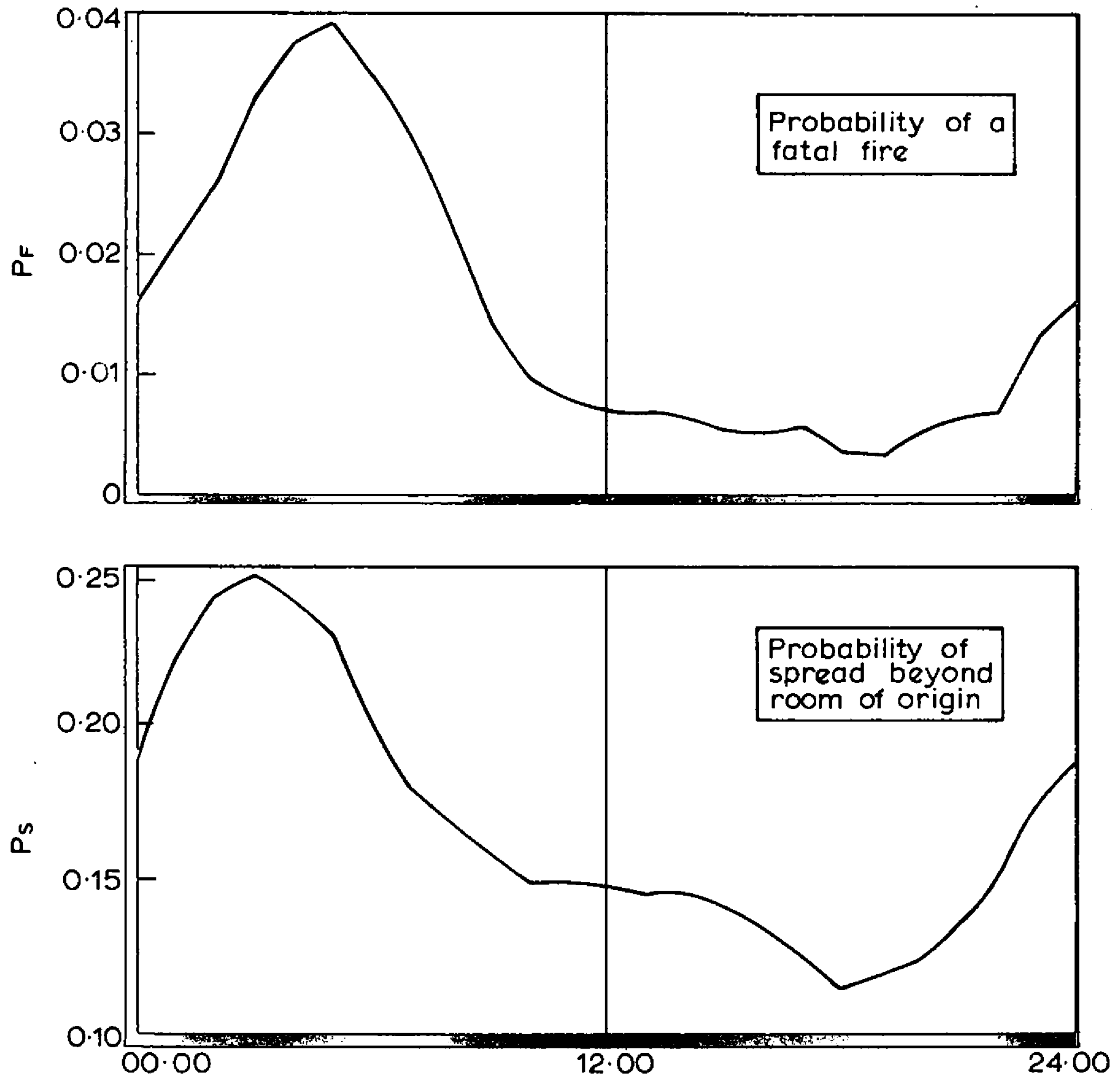

FIG. 2. PROPORTION OF FATAL FIRES (P_F) AND PROBABILITY OF FIRE SPREAD (P_S) BY TIME OF DAY (SMOOTHED DATA)

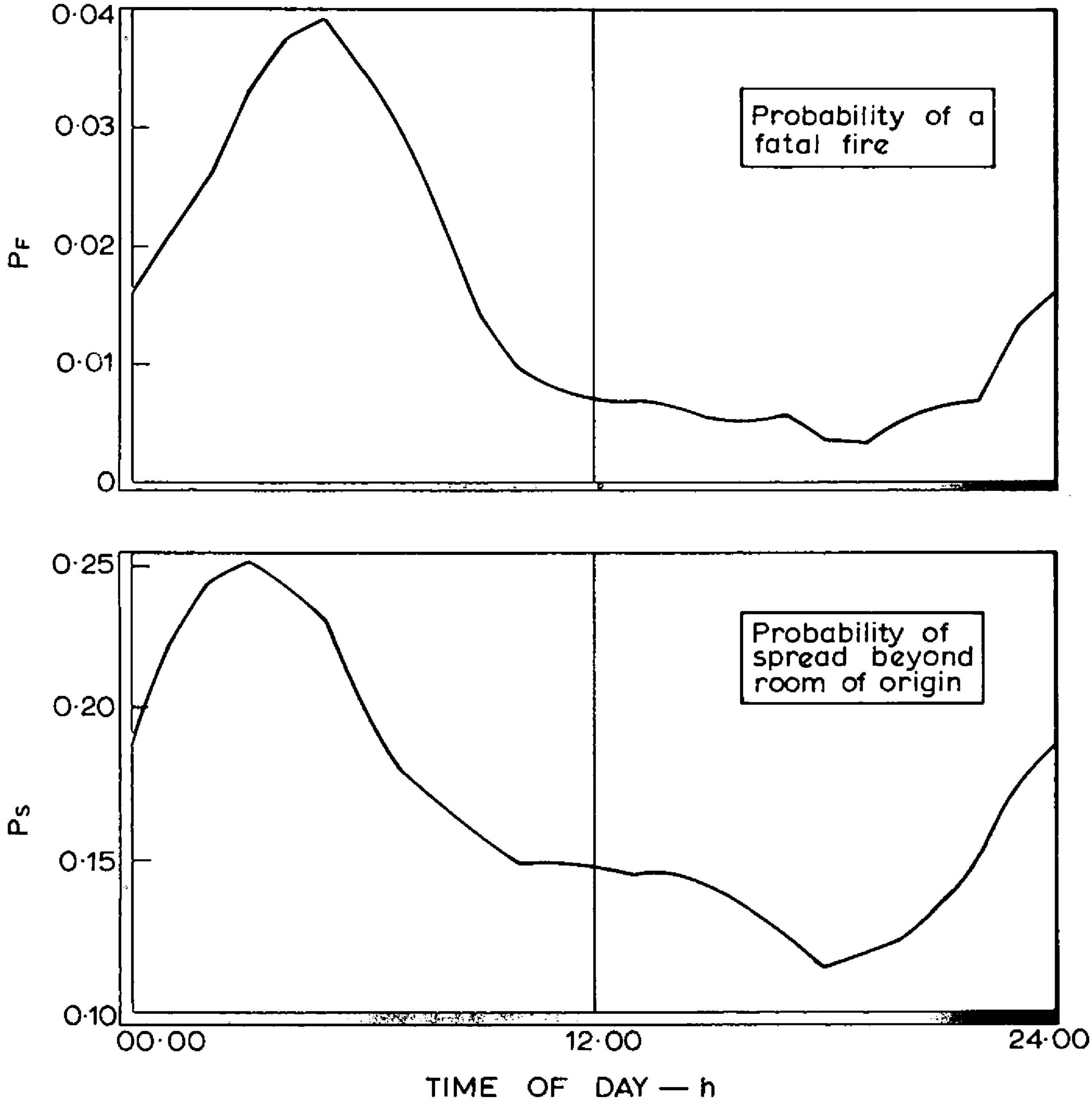

FIG. 2. PROPORTION OF FATAL FIRES (P_F) AND PROBABILITY OF FIRE SPREAD (P_S) BY TIME OF DAY (SMOOTHED DATA)

10962 FR 893

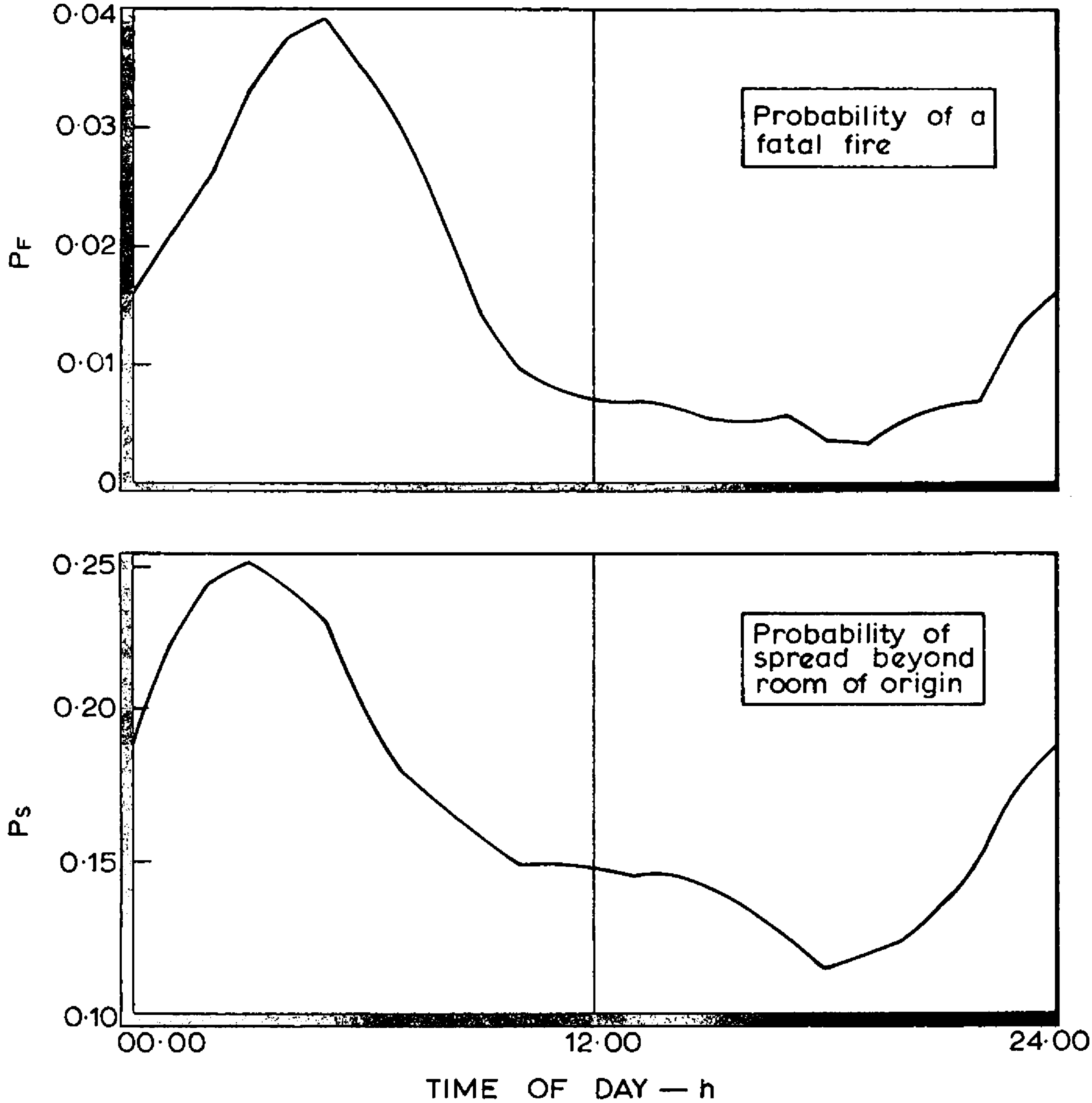

FIG. 2. PROPORTION OF FATAL FIRES (P_F) AND PROBABILITY OF FIRE SPREAD (P_S) BY TIME OF DAY (SMOOTHED DATA)

10962 FR 893