CORRELATION BETWEEN COOL SEASON ENVIRONMENTAL TEMPERATURES AND DENGUE HEMORRHAGIC FEVER (DHF) CASE RATES IN BANGKOK, THAILAND

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OBJECTIVE : To determine if the amplitude of the seasonal cycle of DHF case rates in Bangkok is determined by weather conditions.

BACKGROUND : Reported case rates of DHF in Bangkok follow an annual cycle with peak case rates in the mid-rainy season (June to October), falling case rates in the late rainy season and cool season (November to March) and rising case rates in the hot season (April to May). Although the cycle pattern is relatively constant the amplitude may vary by a factor of ten-fold between mild and severe years. Linear regression analysis of monthly case rates versus total yearly case rates for the years 1962 through 1978 showed that case rates in May of a given year, at the onset of the rainy seasons, are strongly correlated with the total number of cases in that year ($N = 17$), $r = .858$ $p < .001$). Case rates in March of a given year (typically the nadir of DHF activity) are also significantly correlated with the total number of cases in that year ($N = 16$, $r = .696$ $p < .01$). These observations suggested that factor(s) which govern DHF case rates are operative well before the onset of the rainy season. This analysis was undertaken to determine if meteorologic variables played a role in determing the severity of DHF seasons in Bangkok.

METHODS : Meteorologic data from the Bangkok weather bureau was obtained from the Ministry of Communications and analyzed in relationship to DHF rates as recorded by the Ministry of Public Health by linear regression analysis.

Raw data in the form of hourly measurements of temperature, rainfall, wind velocity, and relative humidity made at the Sukhumvit Road Station for the period January 1958 through December 1979 were kindly provided by CPT Khachit Buachitti, RTN, Director-General of the Department of Meteorology. This hourly data was partially processed into monthly data as shown in Table 1 and along with records of DHF per month in the Bangkok area were sent to WRAIR where the remainder of the computational work was done on computers in the Division of Biometrics.

For each of the 11 weather variables, correlations between deviations from the monthly norm of that variable and deviations from the norm of DHF activity for that same month were sought. This was accomplished by deriving the

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correlation coefficient of a weather variable for one calendar month and the DHF activity in that same month over the 17 years interval 1962 through 1978. For example, the mean temperature in each December was plotted against the number of cases in that same month to determine if an unusually warm December was correlated with an unusually large number of cases of DHF in that month (Figure 1). Also, correlations coefficients were derived for each weather variable for each calendar month against the number of cases of DHF in the preceding 18 months and the subsequent 18 months. The analysis of the correlation of weather variables and case rates in preceding months was undertaken as a control; the analysis of the correlation of weather variables and cases rates in following months was undertaken to expose possible delayed influences of meteorological conditions. All correlation coefficients were computed.

Correlation coefficients were also developed for the association of the number of DHF cases in a calendar month with the number of DHF cases in the 18 preceding and 18 subsequent months. And finally correlation coefficients were developed for the association of weather variables over the preceding and subsequent 18 months (e.g., is a warm January associated with a preceding warm December, etc.).

RESULTS : Results are presented in graphic and tabular form. Figures 2, 3, and 4 show the mean (+/- one standard deviation) monthly high, mean and low temperatures, the mean days per month in which the daily 24 hour integrated mean temperature is less than 27°, and the mean rainfall per month in Bangkok for the years 1958 through 1978.

Figure 5 shows the correlation of the average daily 24 hour integrated mean temperature in Decembers (1962-1978) with the number of reported cases of DHF in preceding and subsequent months. It can be seen that the number of cases in a given January or February are correlated with the average daily mean temperature in the preceding December ($r = .720$ and $.709$, respectively, $p < .001$ for both).

Table 2 shows the correlation of weather variables in a given calendar month and the number of reported DHF cases in that same month. All correlations with a $p < .05$ are noted and the sign of the correlation is noted in parentheses. For example the average daily mean temperature in January is positively correlated with the number of DHF cases in that same month with a p value of 0.0007. Table 3 shows a similar analysis between weather variables in a given month and DHF cases in the following month.

In both tables 2 and 3, the only strong associations are those between cool season temperatures and cool season case rates. Especially noteworthy is the lack of any correlation between rainfall and DHF case rates at any time of the year.

Figure 6 shows the correlation of the number of cases in month N with the number of cases in preceding and subsequent months. In contrast with all other months of the year, case rates in December and January correlate weakly with case rates in preceding months but strongly in subsequent months, implying that a "resetting" of the disease activity occurs annually in the cool season.

Figure 7 shows the correlation of the average daily mean temperature in month N with the average daily mean temperature in preceding and subsequent months. The year tends to be broken into two groupings of months : warm December, January's February's March's and April's tend to correlate with each other, while temperatures in Junes, Julys, Augusts, Septembers, and Octobers tend to correlate in a separate cluster. May and November appear to be intermediate months, not associated with either cluster.

With this multitude of interrelated variable, it is difficult to pick out potential causative versus simply associated variables. Nonetheless, by multiple linear regression analysis, temperatures in Decembers correlated with DHF case rates in Januaries even if the case rates in December are held constant (See table 4). The absolute total number of cases in a given year N are weakly correlated with the absolute total number of days that the mean daily temperature was less than 27° in the preceding cool season December (year N-1) and January (year N), as shown in Figure 8. If, however, the change from one year to the next year is analyzed for both the yearly total cases and the cool season total days less than 27°, then a strong correlation emerges (Figure 9). Restated, if the current cool season is cooler than last years cool season, then there is a strong probability that the total number of DHF cases for the rest of this year will be less than last year.

Table 1. Partially Processed Weather Data :

Per Month :

Rainfall total
Days with measurable rainfall
Average daily mean temperature
Days with mean temperature < 27°C
Absolute minimum temperature
Average daily minimum relative humidity
Days with mean relative humidity < 70%
Absolute minimum relative humidity
Average daily mean wind velocity
Days with mean wind velocity $\geq$ 10 km/hr
Maximum daily mean wind velocity

Table 2. Correlation of Weather Variables and Number of Reported DHF Cases in the Same Month, Bangkok, 1962 → 1978 (p Values of Rank Correlations, N = 17)

Weather variable	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
Rain days	-	-	-	-	-	-	-	-	-	-	-	-
Rainfall total	-	(-).02	-	-	-	-	(+).04	-	-	-	-	-
Aver daily mean temp.	-	(+).001	-	-	-	-	-	-	-	(+).02	(+).0007	(+).02
Days mean T < 27°	(-).03	(-).03	-	-	-	(+).02	-	-	-	(-).007	(-).0002	(-).01
Abs min T	-	-	-	-	-	(-).03	-	(+).05	-	-	(+).004	-
Day mean rel humidity < 70%	-	-	-	-	-	-	-	-	-	-	-	-
Aver min rel humid	-	(-).02	-	-	-	-	(+).05	-	-	-	-	-
Abs min rel humid	-	-	-	-	-	-	-	-	-	-	-	-
Days mean wind vel < 10 km/hr	-	-	-	-	-	-	-	(-).05	-	-	-	-
Aver daily mean wind vel	-	-	-	-	-	-	-	-	-	-	-	-
Max daily wind vel	-	-	-	-	-	-	-	-	-	-	-	-

Table 3. Correlation of weather variables in a given calendar month and number of reported DHF cases in the following month, Bangkok 1962 → 1978 (p values of rank correlations, N = 17)

Weather variable	MAR	APR	MAY	JUN	JUL	AUG	SEP	OCT	NOV	DEC	JAN	FEB
Rain days	-	-	-	-	-	-	-	-	-	-	-	-
Rainfall total	-	(-).05	-	-	-	-	(+).02	-	-	-	-	-
Aver daily mean temp.	-	(+).02	-	-	-	-	-	-	-	(+).0008	(+).001	(+).01
Days mean T < 27°C	(-).04	-	-	-	-	(+).05	-	-	-	(-).002	(-).0004	(-).004
Abs min T	-	-	-	-	-	(-).01	(+).03	(-).03	-	(+).07	(+).008	-
Days mean rel humidity < 70%	-	-	-	-	-	-	-	-	-	-	-	-
Aver min rel humid	-	(-).02	-	-	-	-	-	-	-	-	-	-
Abs min rel humid	-	-	-	-	-	-	-	-	-	-	-	-
Days mean wind < 10 km/hr	-	-	-	-	-	-	-	-	-	-	-	-
Aver daily mean wind vel	-	-	-	-	-	-	-	-	-	-	-	-
Max daily wind vel	-	-	-	-	-	-	-	(-).04	-	-	-	-

Table 4. Partial correlation coefficients

Variable			r			
X	Y	Z	Y-Z	X-Z	X-Z(y constant)	P
$Temp_{Dec}$	$Cases_{Dec}$	$Cases_{Jan}$	+.88	-.727	-0.47	<.05
$Temp_{Dec}$	$Cases_{Dec}$	$Cases_{Jan}$	+.88	-.730	-0.43	<.05

Figure 1.

Cases in month of December vs average daily mean temperature in December, 1962 – 1978.

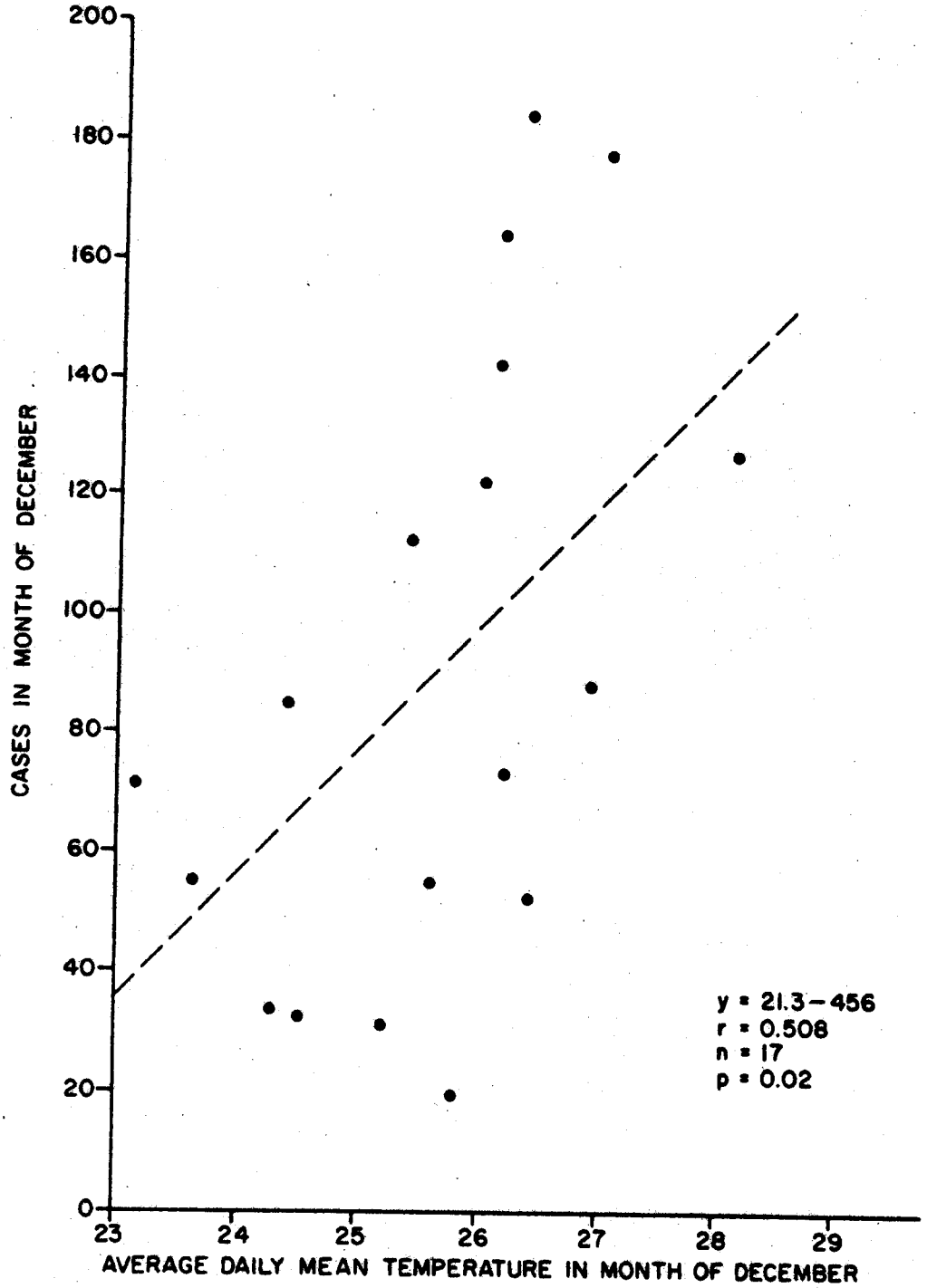


Figure 2.

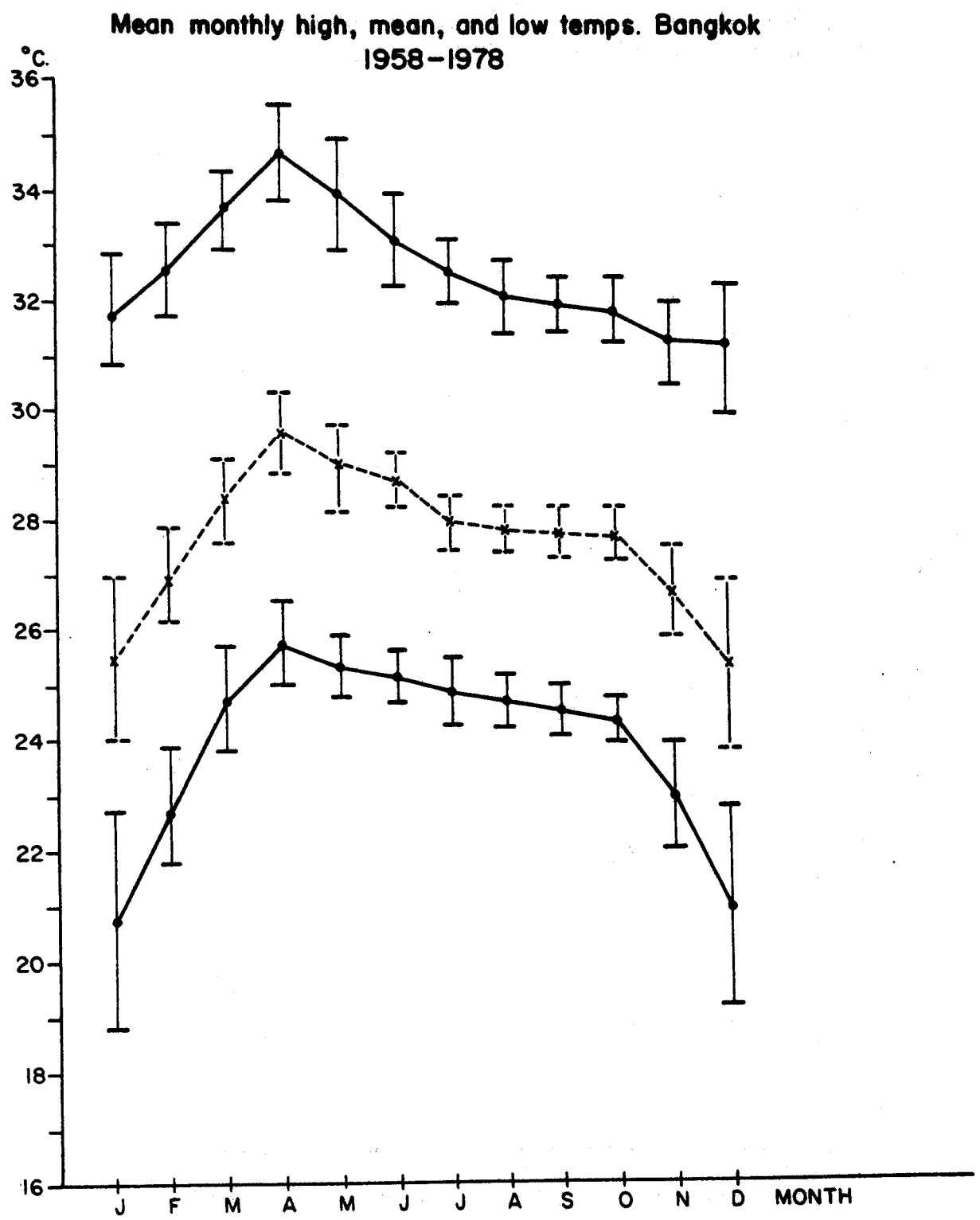

Mean monthly high, mean, and low temps. Bangkok
1958-1978
°C.
36
34
32
30
28
26
24
22
20
18
16
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

Figure 3.

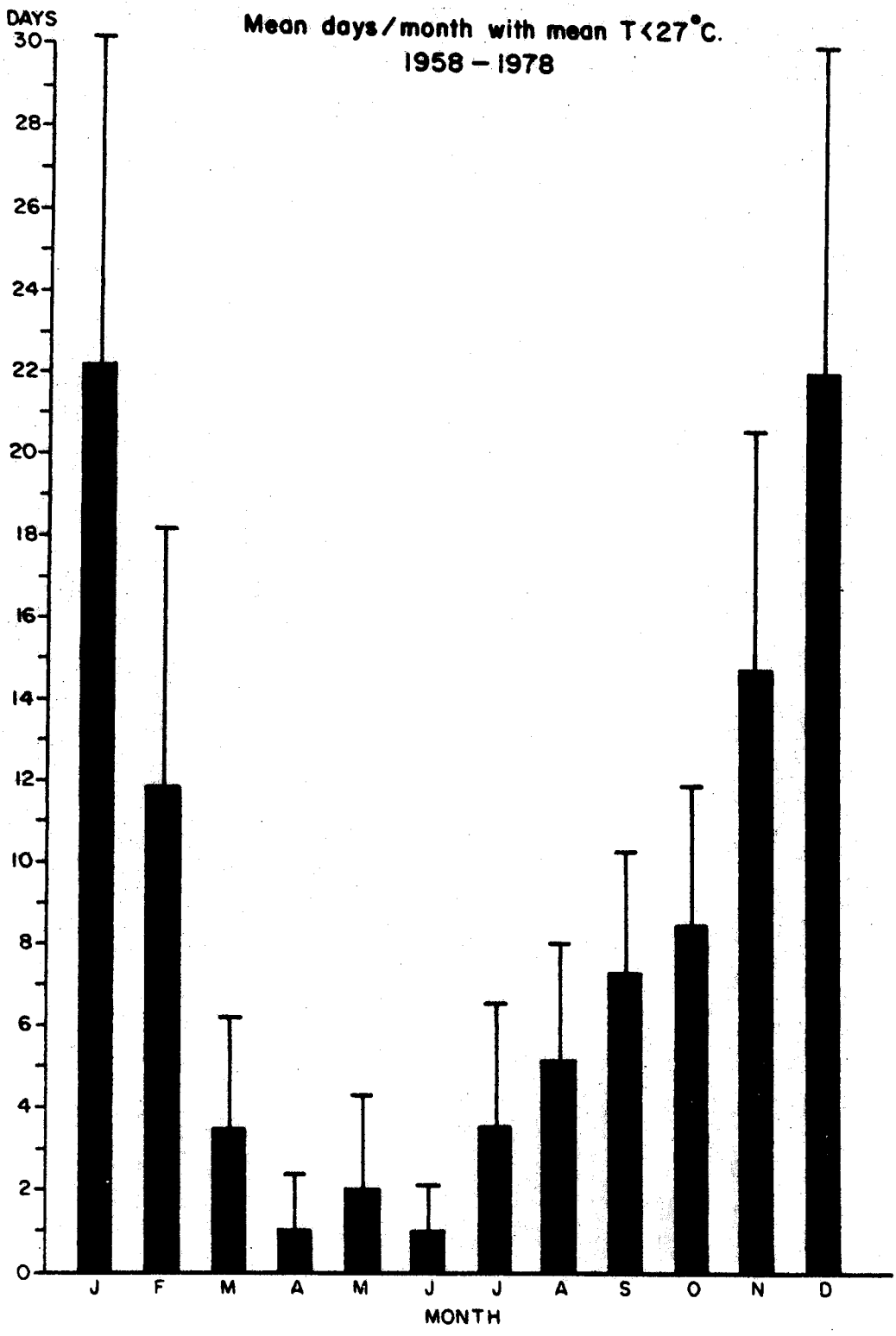

Mean days/month with mean T<27°C.
1958 – 1978
DAYS
30
28
26
24
22
20
18
16
14
12
10
8
6
4
2
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

Figure 4.

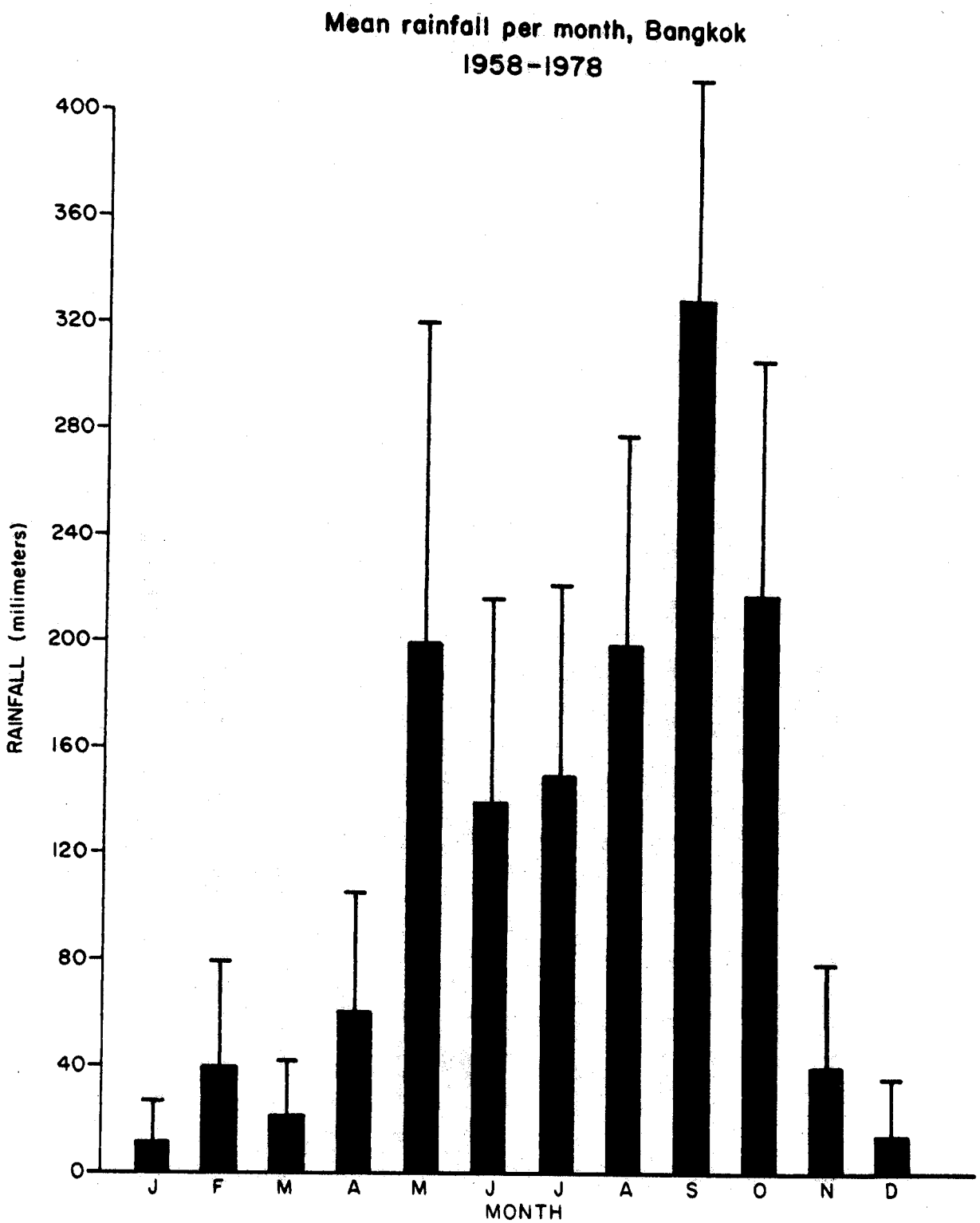

Mean rainfall per month, Bangkok
1958-1978
RAINFALL (milimeters)
400
360
320
280
240
200
160
120
80
40
0
J
F
M
A
M
J
J
A
S
O
N
D
MONTH

Figure 5. Correlation of average daily mean temperature in Decembers (1962-1978) with number of reported DHF cases in preceding and subsequent months (rank correlation; N = 17)

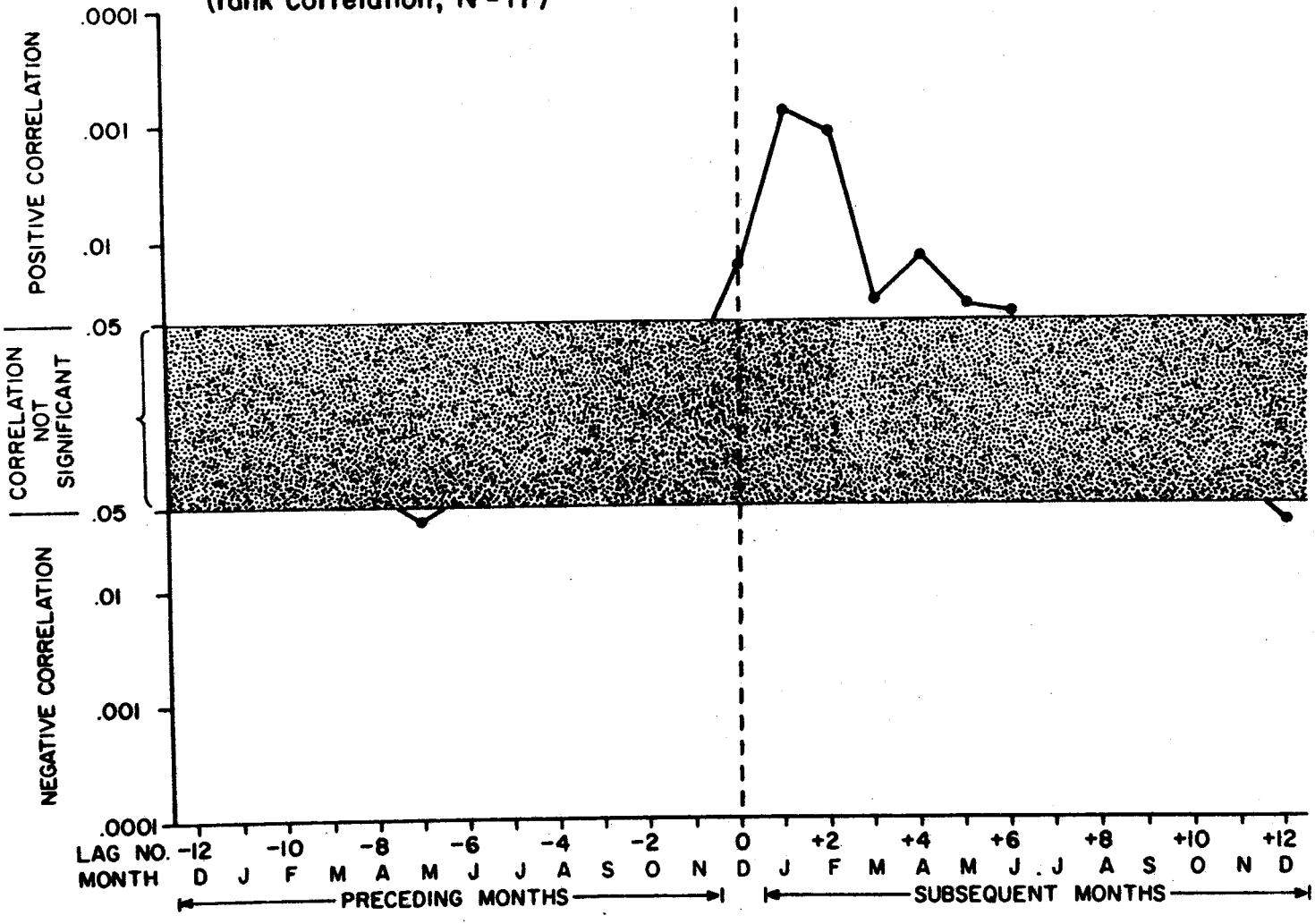


Figure 6.

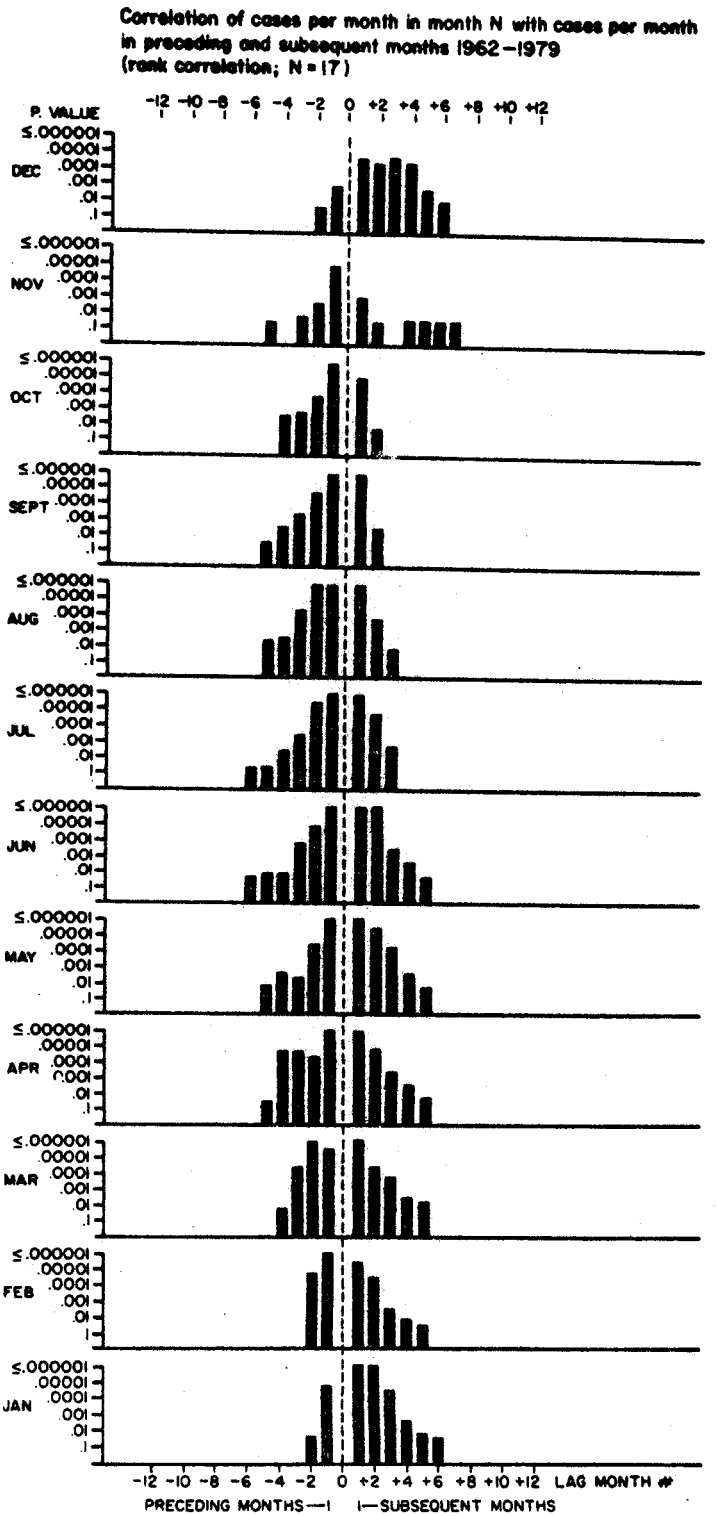

Correlation of cases per month in month N with cases per month in preceding and subsequent months 1962–1979
(rank correlation; N = 17)
P. VALUE
≤.000001
.00001
.0001
.001
.01
.1
DEC
NOV
OCT
SEPT
AUG
JUL
JUN
MAY
APR
MAR
FEB
JAN
-12 -10 -8 -6 -4 -2 0 +2 +4 +6 +8 +10 +12
LAG MONTH #
PRECEDING MONTHS
SUBSEQUENT MONTHS

Figure 7.

Correlation of Average mean daily temperature for index month vs preceding and subsequent months (rank correlation; N=17)

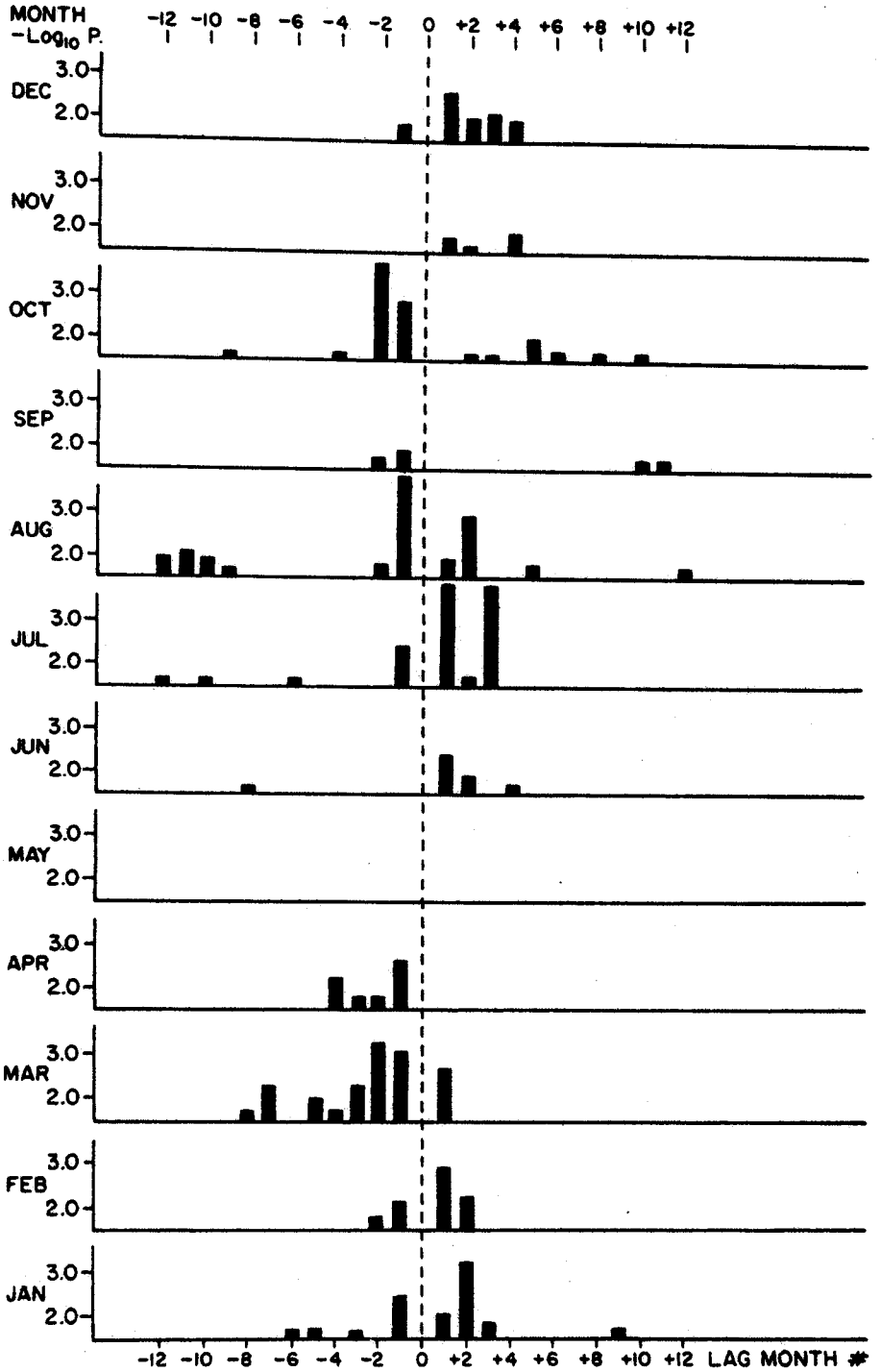


Figure 8.

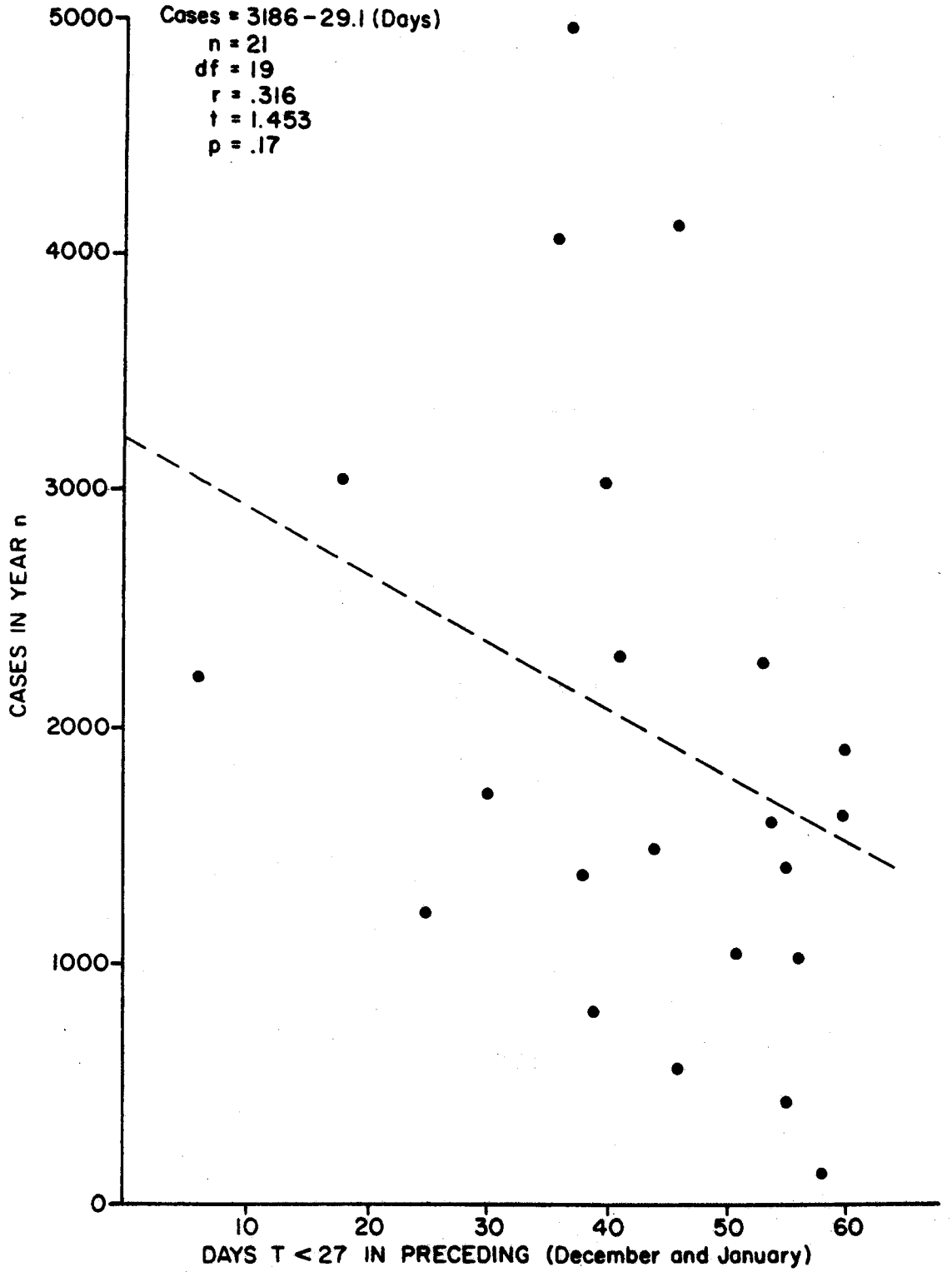
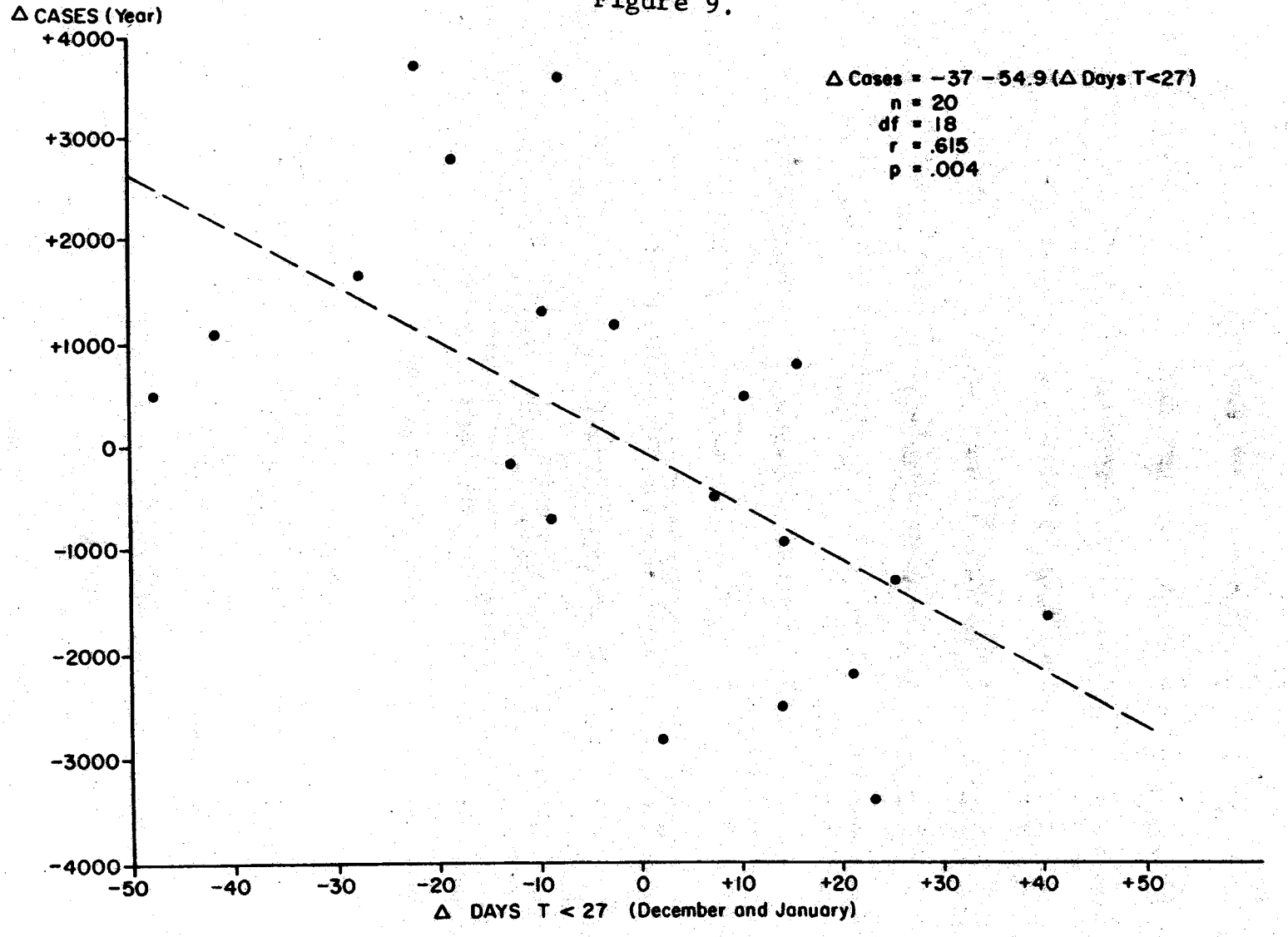

Cases = 3186 - 29.1 (Days)
n = 21
df = 19
r = .316
t = 1.453
p = .17
5000
4000
3000
2000
1000
0
CASES IN YEAR n
10
20
30
40
50
60
DAYS T < 27 IN PRECEDING (December and January)

Figure 9.


Δ CASES (Year)
+4000
+3000
+2000
+1000
0
-1000
-2000
-3000
-4000
Δ Cases = −37 −54.9 (Δ Days T<27)
n = 20
df = 18
r = .615
p = .004
-50
-40
-30
-20
-10
0
+10
+20
+30
+40
+50
Δ DAYS T < 27 (December and January)