

Note on the After-shocks of the Hokkaido Earthquake of March 22nd 1894.

BY

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The time and space distribution of the after-shocks of the great Kumamoto (1889), Mino-Owari (1891), and Kagoshima (1893) earthquakes has already been discussed in Vol. VII of the Journal of the College of Science, where it was shown amongst other things that the relation between their frequency (y) and the time (x) is very nearly expressed by the following equation,

$$y = \frac{k}{h + x}, \quad (1)$$

h and k being constants. Let us here examine whether the after-shocks of the Hokkaido earthquake follow the same law of frequency-decrease, the necessary data being given in tables I to IV, appended to the present note.

The after-shocks of this earthquake, which took place on March 22nd 1894, at 7^h 56^m p.m., were successfully recorded at the Meteorological Observatory of Nemuro, about 120 km. from the epicentre, their numbers during the first five days being given in the 3rd column of the following list.

NUMBER OF THE AFTER-SHOCKS OBSERVED AT NEMURO.

x	Date. March, 1894.	Actual daily frequency corresponding to x.	y, the calculated value of the daily frequency.
0	From the 23rd, noon, to the 24th, noon.	88	89,6
1	" 24th " 25th	42	42,2
2	" 25th " 26th	31	27,9
3	" 26th " 27th	19	20,6
4	" 27th " 28th	16	16,3

Calculating by the method of Least Squares from the number of the after-shocks actually observed during these five days, equation (1) assumes the following form :—

$$y = \frac{79.9}{x+0,8896}, \quad (2)$$

in which y is the after-shock frequency, and x the time expressed in days, its origin corresponding to the 24 hours interval between the noons of the 23rd and the 24th of March 1894. The frequency for $x=0, 1, 2, 3, 4$, calculated by this equation agrees, as shown in the 4th column of the above table, very closely with the actual values.

As a verification, let us calculate by equation (2) the number of shocks at Nemuro during the 3rd and 4th years after the first great earthquake. Now the middle day of the 3rd year, April 1896–March 1897, is represented by $x=x_1 = 923$; and that of the 4th year, April 1897–March 1898, by $x=x_2 = 1288$. The values of y which correspond to these values of x are found, by equation (2), to be :

$$\begin{array}{ll} \text{for } x=x_1, & y=y_1=0,0865 ; \\ \text{and} & \text{for } x=x_2, & y=y_2=0,0620. \end{array}$$

The approximate numbers of shocks at Nemuro during these two years would therefore, according to equation (2), respectively be

$$\begin{array}{ll} \text{(for the 3rd year)} & n'_1 = 365 \times y_1 = 32, \\ \text{and} & \text{(for the 4th year)} & n'_2 = 365 \times y_2 = 23. \end{array}$$

But equation (2), which has been deduced from the observed numbers of shocks during the five days immediately after the initial great earthquake, is to be regarded as giving the Nemuro seismic frequency, only so far as the after-shocks are concerned. To obtain the correct result we must therefore add to the above values of n'_1 and n'_2 the average annual number of ordinary earthquakes at the same place, which according to seismic observations during the nine years 1885–1893, is 39. (See Table III). Hence

$$n_1 = n'_1 + 39 = 71,$$

and

$$n_2 = n'_2 + 39 = 62$$

are the estimated numbers of earthquakes we are seeking.

Further,

$$n_1 + n_2 = 133.$$

As a matter of fact there were at Nemuro during the two years under consideration respectively 87 and 52 earthquakes, amounting altogether to $87 + 52 = 139$. In discussions of this sort, these numbers are to be regarded as being practically identical respectively with the calculated results n_1 , n_2 and $(n_1 + n_2)$.

The relation between the time and the seismic frequency at Nemuro is graphically illustrated in figs. 1 and 2.

TABLE I.—HOURLY EARTHQUAKE NUMBER AT NEMURO.

(From the 22nd to the 31st March, 1894).

Day Hour	22	23	24	25	26	27	28	29	30	31
0— 1 a.m.	...	6	7	0	2	0	0	0	0	0
1— 2	...	4	1	1	1	0	0	0	0	0
2— 3	...	4	2	1	0	1	1	0	0	1
3— 4	...	12	1	1	2	0	1	0	0	1
4— 5	...	15	0	2	3	1	1	0	0	0
5— 6	...	10	4	2	1	0	3	0	0	0
6— 7	...	7	6	2	1	1	0	0	1	0
7— 8	...	4	4	3	1	2	4	0	1	0
8— 9	...	7	2	1	1	1	0	0	0	1
9—10	...	2	2	2	1	0	0	0	0	0
10—11	...	1	2	2	1	0	0	1	0	0
11—12	...	8	0	2	1	1	0	0	0	0
0— 1 p.m.	...	10	3	1	2	0	0	1	0	0
1— 2	...	4	1	2	0	0	0	0	0	0
2— 3	...	3	0	3	0	0	0	0	0	1
3— 4	...	7	2	1	2	0	0	0	0	0
4— 5	...	3	2	2	1	0	0	0	0	1
5— 6	...	2	3	1	1	1	0	1	0	0
6— 7	...	5	2	1	1	0	0	0	2	1
7— 8	1	8	2	2	1	0	1	0	0	0
8— 9	16	4	1	0	2	2	0	0	0	1
9—10	13	5	6	2	0	2	0	0	0	0
10—11	7	1	0	0	1	0	0	0	0	0
11—12	13	4	1	1	1	1	0	0	0	1
Sum	50	136	55	35	27	13	11	3	4	8

TABLE II.—DAILY EARTHQUAKE NUMBER AT NEMURO.
(From March 22nd to Dec. 31st, 1894).

Month Day	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1	...	4	2	3	1	0	2	0	0	0
2	...	4	4	2	3	1	3	2	0	2
3	...	3	0	0	0	1	0	1	0	0
4	...	8	2	0	0	2	0	3	0	3
5	...	5	1	1	1	0	3	1	1	0
6	...	4	2	1	0	0	1	2	0	0
7	...	7	0	1	1	0	1	1	1	1
8	...	2	1	2	2	0	3	1	2	1
9	...	4	1	3	0	0	1	1	0	0
10	...	6	5	3	0	2	1	0	0	0
11	...	11	0	1	0	1	0	0	0	0
12	...	8	3	3	2	1	0	1	0	0
13	...	6	0	0	1	0	0	1	0	0
14	...	2	1	1	1	0	1	1	2	0
15	...	3	3	0	0	0	0	1	1	0
16	...	2	1	2	0	0	1	1	0	3
17	...	1	3	0	0	0	0	2	1	1
18	...	3	0	0	1	2	1	1	1	0
19	...	2	3	2	1	1	1	2	1	1
20	...	2	1	0	3	0	0	0	1	0
21	...	2	1	1	3	0	1	1	1	0
22	50	1	6	1	0	0	0	0	1	0
23	136	5	0	0	0	0	0	2	0	0
24	55	3	2	0	1	0	0	3	0	0
25	35	3	0	1	0	2	1	0	0	0
26	27	0	3	2	0	0	1	0	0	0
27	13	3	0	1	1	1	0	0	2	0
28	11	2	0	4	1	3	0	0	1	0
29	3	4	0	1	0	0	1	1	1	0
30	4	1	0	3	1	3	0	1	0	0
31	8	...	0	...	0	0	...	0	...	0
Sum	342	111	45	39	24	20	23	30	17	12

TABLE III.—MONTHLY EARTHQUAKE NUMBER AT NEMURO.
(1894—1898.)

Month Year	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII
1894	...	...	363	111	45	39	24	20	23	30	17	12
1895	11	10	12	16	11	8	10	10	11	10	7	11
1896	4	3	7	5	7	7	15	6	11	1	6	8
1897	5	6	7	6	5	9	3	6	2	6	2	4
1898	4	3	1	3	5	2	1	3	4	10	6	2
Sum	24	22	27	30	28	26	52	42	47	47	32	35 (A)
	13	12	15	14	17	18	28	22	24	17	15	23 (B)
	23	21	25	22	35	34	29	27	31	33	34	38 (C)

(A), (B) and (C) are the monthly sums deduced respectively from the eqke numbers for the 4 yrs July 1894–June 1898 ; 3 yrs, July 1895–June 1898 ; and 9 yrs, January 1885–December 1893.

The following monthly and seasonal distributions of earthquakes at Nemuro have been obtained by adding (B) and (C).

Month	I	II	III	IV	V	VI	VII	VIII	IX	X	XI	XII	Sum
Number of earthquakes	36	33	40	36	52	52	57	49	55	50	49	61	570 (D)

Spring (III, IV, V)	128	} Warmer months (IV—IX)	301
Summer (VI, VII, VIII)	158		
Autumn (IX, X, XI)	154	} Colder months (X—III)	269
Winter (XII, I, II)	130		
Sum	570	Sum	570

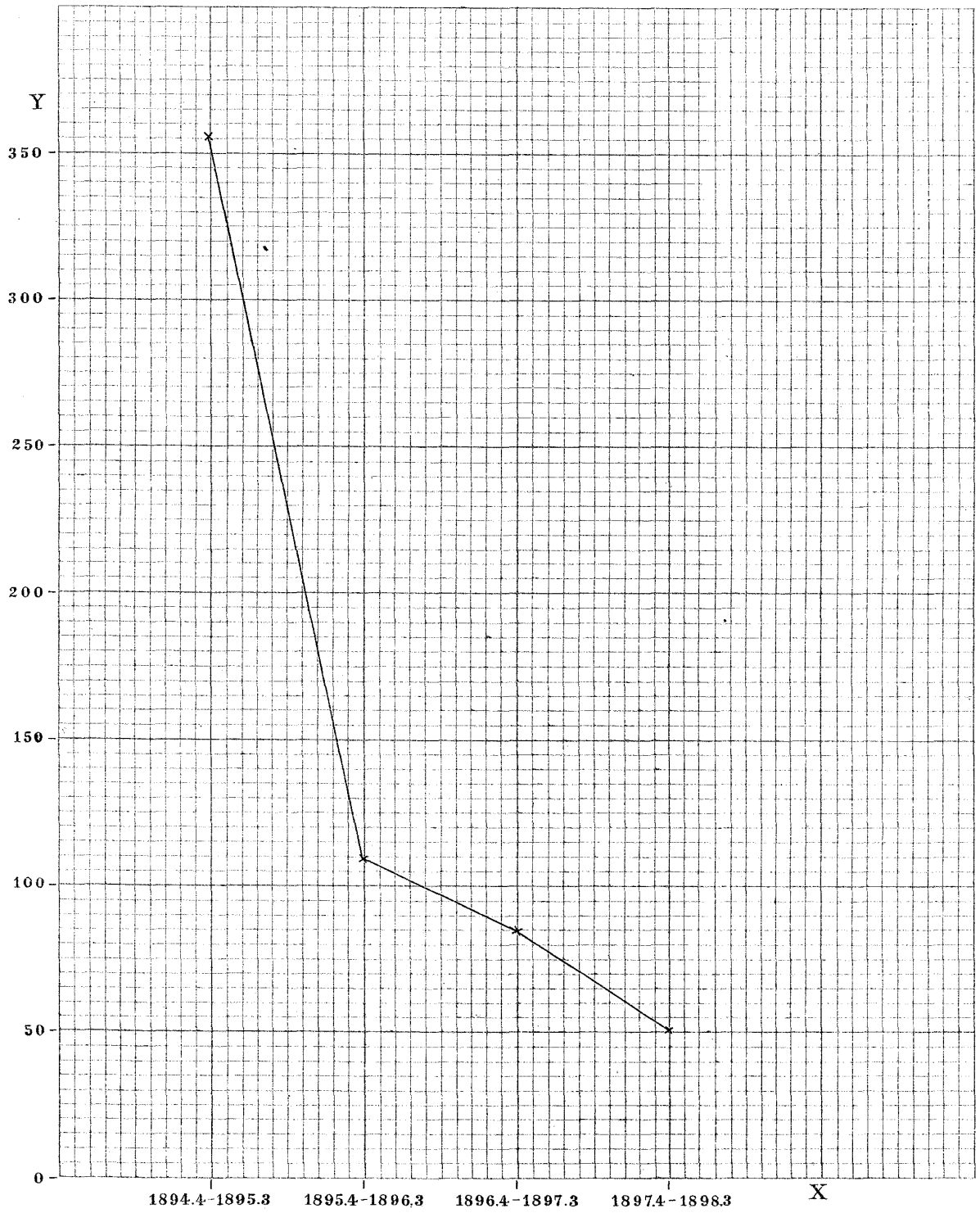
TABLE IV.—MONTHLY EARTHQUAKE NUMBER AT NEMURO.
(1885—1893.)

Month Year	I	II	III	IV	V	V	VII	VIII	IX	X	XI	XII	Sum
1885	0	0	3	1	1	4	5	1	4	7	6	1	33
1886	2	5	4	3	3	3	2	4	4	5	2	6	43
1887	2	2	0	2	7	2	5	5	1	1	3	3	33
1888	0	3	4	0	1	2	1	2	1	2	1	1	18
1889	6	3	1	3	7	2	7	3	6	3	3	4	48
1890	3	3	3	6	7	6	0	3	4	2	10	7	54
1891	2	3	7	3	2	3	3	3	2	4	2	11	45
1892	5	1	1	2	3	0	2	1	4	5	3	3	30
1893	3	1	2	2	4	12	4	5	5	4	4	2	48
Average	23	21	25	22	35	34	29	27	31	33	34	38	352

Mean Yearly Number... ..39

Spring	(III, IV, V)	82
Summer	(VI, VII, VIII)	90
Autumn	(IX, X, XI)	98
Winter	(XII, I, II)	82
	Sum	<u>352</u>

Fig. 1. Frequency of Nemuro After-shocks.

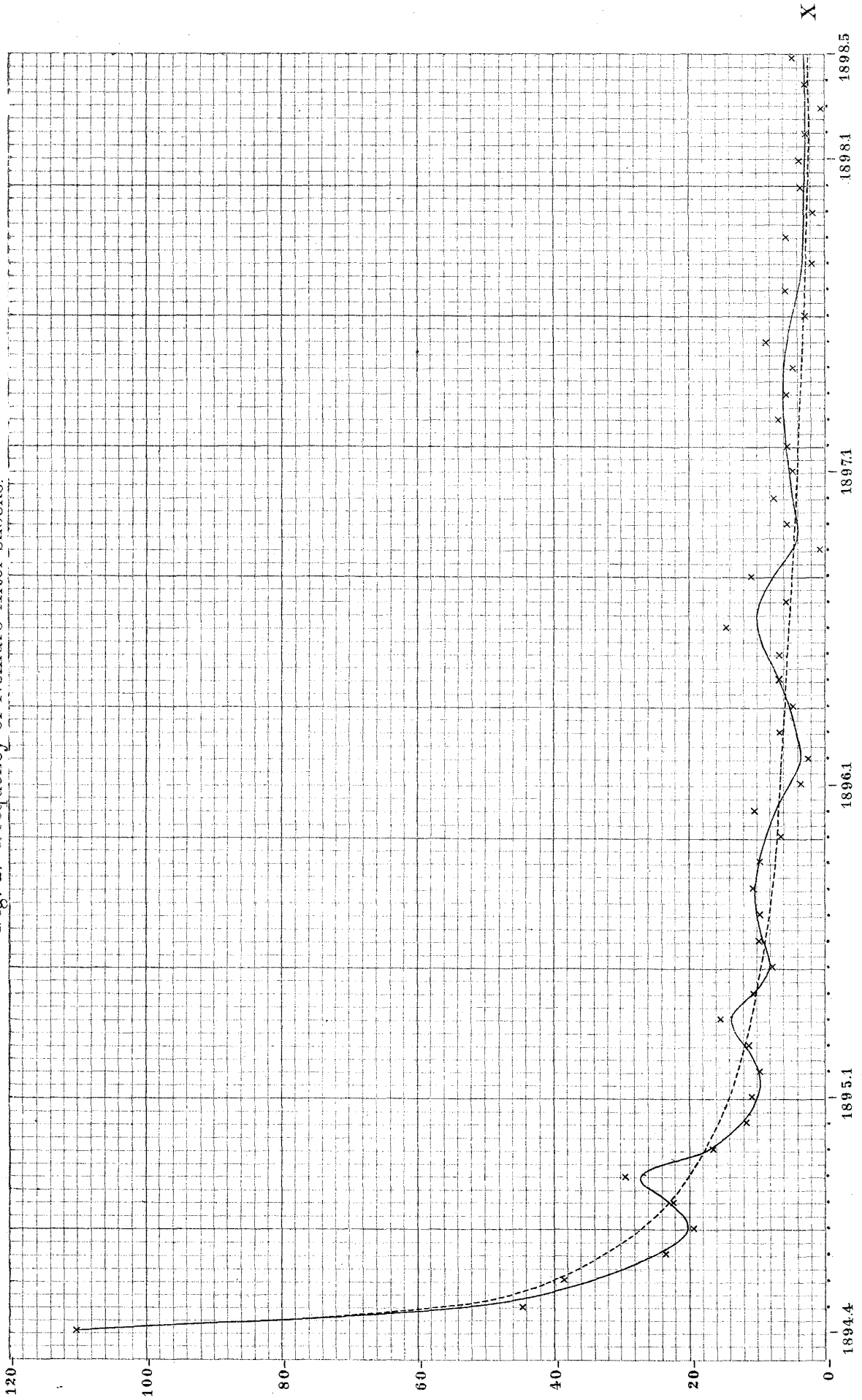


X=Time in years.

Y=Number of earthquakes during 12 months.

Y

Fig. 2. Frequency of Nemuro After-shocks.



X = Time, in months.

Y = Monthly number of earthquakes.