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SEA SURFACE TEMPERATURE MONTHLY AVERAGE AND ANOMALY CHARTS EASTERN TROPICAL PACIFIC OCEAN, 1947-58

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by

James A. Renner

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by

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ABSTRACT

Sea temperature data in the area bounded by the west coast of the Americas to longitude 120° W. and latitude 30° N. to 20° S. and temperature data at three coastal stations in South America are presented in two parts. Part I consists of 12 monthly average charts based on data from 1947 through 1958, and Part II consists of 144 monthly anomaly charts derived from the average charts.

INTRODUCTION

As a byproduct of environmental studies of the temperate tunas of the Pacific Ocean, Johnson (1961) has published sea surface temperature monthly average and anomaly charts for the northeastern Pacific covering the period 1947-58. The charts presented here are a continuation of sea temperature studies for the same years in the eastern tropical Pacific Ocean. They were prepared for two purposes. The first was to provide information for investigating possible relationships between anomalous sea surface temperatures and variations in the distribution and availability of the tropical tunas. The second was to produce the 12-year monthly average charts to be used as a base upon which to construct current sea temperature anomaly charts. These appear monthly in the Bureau of Commercial Fisheries publication, *California Fishery Market News Monthly Summary*, Part II - Fishing Information. Since January 1960 temperature anomalies from the long-term mean for the temperate Pacific have been presented monthly in this publication, but, heretofore, no satisfactory mean has been available for construction of similar charts for the tropical Pacific.

DATA SOURCE AND TREATMENT

The oceanic temperature data presented are injection temperatures[1] taken by merchant and naval ships cooperating with the U. S. Weather Bureau. These data were made available by the Laboratory Director, Bureau of Commercial Fisheries Biological Laboratory, Stanford, Calif. Scientists at that laboratory have obtained historical records of sea temperatures and other marine meteorological observations from the National Weather Records Center, Asheville, N. C., to assist them in their oceanographic studies of the Pacific Ocean.

The probability that injection temperatures are subject to errors was discussed by

[1] Injection temperatures are obtained from a thermometer installed in the sea water intake system used for cooling the ship's engines.

Johnson (1961). Injection temperatures used here were not thoroughly edited, and the data presented should be considered a first approximation for early use. The Bureau of Commercial Fisheries Biological Laboratory, Stanford, will publish critically edited data in the future for broader regions of the Pacific Ocean. The mean monthly number of injection temperature observations by 2-degree squares of latitude and longitude computed from the pooled 12 years of data and is shown in figure 1. Squares with fewer than two observations are not shown.

Coastal sea temperatures at La Libertad, Ecuador, for the 12-year period, and temperatures at Puerto Chicama, Peru, for 1957 and 1958, were obtained through the courtesy of the Inter-American Tropical Tuna Commission. Temperatures for 1947 through 1956 at Puerto Chicama were extracted from a report by Rodewald (1958). Temperatures at Talara, Peru, for 1947 through 1955 were taken from the U. S. Department of Commerce, Coast and Geodetic Survey, Special Publication No. 280 (1956), and temperatures for 1956 through 1958 were obtained by direct communication with that Department.

The locations of these stations are:

Station	Latitude	Longitude
La Libertad, Ecuador	02°13' S.	80°55' W.
Talara, Peru	04°35' S.	81°17' W.
Puerto Chicama, Peru	07°42' S.	70°27' W.

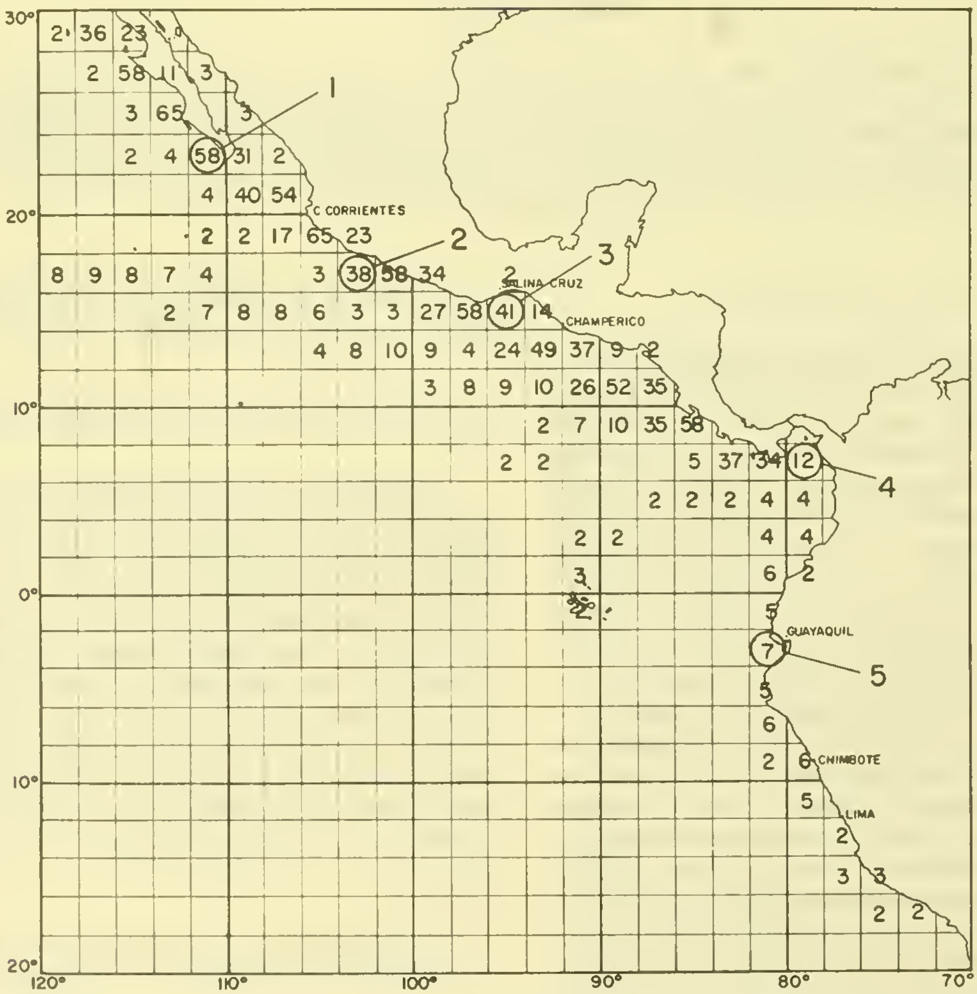

Figure 1.--Mean monthly number of injection temperature observations by 2-degree squares. Circled areas 1 to 5 denote squares chosen for variability analysis of the source data.

Monthly temperature summaries to the nearest 0.1° F. by 2-degree squares for the region bounded by the west coast of the Americas to longitude 120° W. and latitude 30° N. to 20° S. were extracted from the historical records to form 12-year (1947-58) monthly averages, which are presented in Part I. Two or more observations were required in any month before a 2-degree summary was utilized from the records. In the monthly average charts, covering the 12-year period, temperatures are listed only when 6 or more years were represented; the number in the upper right-hand corner of each 2-degree square denotes the number of years that were included in the average. Each year's data received equal weight.

Monthly charts presented in Part II show anomalies to the nearest 0.1° F. by 2-degree squares for each month of each year for 1947-58. Shaded squares indicate regions colder than average, and unshaded squares indicate warmer than or no deviation from the average.

Twelve-year (1947-58) monthly means to the nearest 0.1° F. for the three coastal stations are presented in Part I. Monthly anomalies for the coastal stations, included in Part II, are based on these 12-year monthly means. Plus values indicate temperatures warmer than mean and minus values colder than mean.

Because the area bounded by latitude 20° N. to 30° N. and longitude 110° W. to 120° W. is the general region of overlap of the temperate and tropical tuna fisheries of the eastern Pacific Ocean, charts of this region are presented here as well as in the report by Johnson (1961). Minor differences between the two reports that appear in the average charts for this region are due to additional superficial editing which occurred since the publication of the report for the temperate region. Differences should be resolved in favor of charts presented here.

Average temperatures and anomalies for the region south of the equator should be viewed with caution. For the most part, adequate temperatures were available only for squares contiguous to the coast of South America. Because of coastal upwelling, this is a region of sharp horizontal temperature gradient. Deviation of the position of a ship with respect to the "normal" shipping lane could cause a considerable bias in the averages and anomalies. Depending on ships' positions within a 2-degree square, reported injection temperatures might vary as much as 10° F. In a 2-degree square represented by a minimum of two observations, this type of bias becomes increasingly significant.

Because of the limited number of observations available for the region south of the Equator and the attendant possible bias described above, it is recommended that the temperatures and anomalies shown for that area be compared with data presented by other authors.

Wooster (1961) has published yearly isograms of average sea surface temperatures by 1-degree squares from latitude 4° S. to 18° S. for the years 1939-56, based on "Mapas Mensuales" of the Peruvian Compañia Administradora del Guano.

Another report presenting temperature data of the eastern tropical Pacific Ocean is that of Bjerknes (1961) in a study of "El Niño" conditions off the South American coast. This report, however, does not provide monthly temperature values but, rather, features long-term seasonal averages and their corresponding progressive changes for the years 1935-57.

RELIABILITY OF THE DATA

In order to present some indication of the variability of unedited source data, confidence intervals of the charted means and anomalies were calculated for five selected 2-degree squares. The circled areas shown in the density chart (fig. 1) are the 2-degree squares chosen to represent areas featuring the general characteristics listed below.

Square 1. Cape San Lucas frontal zone - sharp horizontal thermal gradient and expected large temperature change in time and space.

Square 2. Off central Mexico - little expected temperature change in time and space.

Squares 3 and 4. Gulfs of Tehuantepec and Panama - large expected temperature variability, especially in winter months because of coastal upwelling, and also thermal ridging in the case of the Gulf of Tehuantepec.

Square 5. Off Gulf of Guayaquil - sharp horizontal temperature gradient and expected large temperature change in time and space. This region had comparatively few observations per unit area.

Standard deviations were computed for the individual monthly means and the corresponding 12-year means for January, April, July, and October of each year. The reliabilities of these means as indicated by the 95 percent confidence interval, for the index squares described above, are shown in table 1. Asterisks denote cases where the presence of gross errors in the source data were responsible for the wide confidence intervals. All other cases having noticeably wide limits had relatively small numbers of observations.

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Table 1.--Mean temperature and 95% confidence interval (°F), and sample size in five selected 2-degree squares

Year	January x̄	January ±	January n	April x̄	April ±	April n	July x̄	July ±	July n	October x̄	October ±	October n
					Index square 1							
1947	70.0	8.6	3	66.0	1.6	9	*74.4	4.3	30	78.5	1.2	36
1948	71.1	0.8	28	69.5	1.2	35	77.8	2.0	22	*78.8	4.0	19
1949	*67.4	5.6	26	67.5	1.4	30	74.4	2.5	26	78.9	1.0	31
1950	70.2	1.2	23	66.4	1.1	40	74.3	1.2	56	81.1	0.8	37
1951	71.2	1.3	33	63.7	1.2	45	76.2	1.8	36	83.9	0.6	52
1952	*73.1	2.1	52	68.0	1.1	45	75.8	1.3	56	83.0	0.6	73
1953	72.4	0.8	71	67.0	0.9	70	75.2	1.3	49	81.8	0.7	61
1954	70.3	1.7	8	67.2	0.9	61	73.7	1.7	23	78.1	0.9	57
1955	69.2	1.0	54	65.9	1.2	29	--	--	0	75.0	1.2	74
1956	69.8	0.8	83	63.8	0.7	94	81.0	0.9	117	82.6	0.5	102
1957	72.0	0.4	93	67.5	0.9	94	77.7	0.6	134	80.6	0.6	97
1958	74.9	0.5	88	71.1	0.5	125	79.5	0.6	154	83.1	0.5	107
1947-58 (unweighted)	71.0	1.2	12	67.0	1.3	12	76.4	1.6	11	80.4	1.7	12
					Index square 2							
1947	--	--	0	78.9	1.9	9	87.3	1.3	12	85.7	0.7	20
1948	82.5	1.0	19	83.4	0.8	27	85.6	0.7	17	85.9	1.9	7
1949	82.5	0.8	17	80.1	2.2	14	85.8	0.6	20	84.9	0.8	22
1950	82.3	0.9	15	79.8	0.8	21	85.9	0.4	38	83.7	0.6	24
1951	80.1	0.9	23	79.4	0.9	33	85.2	0.8	23	86.0	0.7	28
1952	*81.6	5.2	24	81.3	1.0	29	84.9	0.6	30	85.1	0.5	47
1953	80.8	0.7	53	81.2	0.8	42	--	--	0	86.0	0.4	49
1954	83.2	0.6	35	81.6	0.7	42	85.0	0.4	47	84.4	0.3	59
1955	*78.7	2.6	48	79.9	0.7	51	84.2	0.4	48	83.7	0.5	52
1956	*79.4	2.8	53	81.1	0.5	56	84.9	0.4	71	85.2	0.4	53
1957	*81.6	1.2	52	80.6	0.6	68	86.8	0.4	67	86.1	0.4	60
1958	82.8	0.7	49	80.7	0.5	66	86.1	0.4	74	85.5	0.4	61
1947-58 (unweighted)	81.4	1.0	11	80.7	0.8	12	85.6	0.6	11	85.2	0.5	12
					Index square 3							
1947	79.0	50.8	2	85.9	1.6	7	86.0	1.1	13	83.7	2.3	12
1948	78.2	1.8	25	84.3	0.9	26	85.2	0.7	20	80.4	3.4	7
1949	78.3	1.5	20	85.1	1.3	17	84.8	0.7	18	83.9	1.1	15
1950	75.6	3.4	15	81.8	1.3	29	84.4	0.3	44	*78.2	5.5	28
1951	76.6	1.5	25	*80.5	4.7	33	84.9	0.6	23	*82.9	2.2	28
1952	82.2	1.1	25	84.9	1.1	36	84.7	0.8	20	80.8	1.8	39
1953	77.3	1.2	43	84.8	0.5	41	85.4	0.5	30	82.7	0.9	43
1954	79.4	1.1	44	83.2	0.8	53	84.3	0.5	46	82.1	1.0	39
1955	78.7	1.6	42	82.8	0.6	54	83.2	0.5	54	82.3	1.3	51
1956	76.0	1.5	57	84.7	0.6	56	84.5	0.5	78	83.4	0.7	53
1957	78.7	1.3	60	85.1	0.5	67	85.9	0.4	63	84.5	0.7	64
1958	80.8	0.8	66	84.6	0.4	80	85.7	0.5	64	85.4	0.4	62
1947-58 (unweighted)	78.4	1.2	12	84.0	1.0	12	84.9	0.5	12	82.5	1.2	12

Table 1.--Mean temperature and 95% confidence interval (°F), and sample size in five selected 2-degree squares--Continued

Year	January $\bar{x}$	January ±	January n	April $\bar{x}$	April ±	April n	July $\bar{x}$	July ±	July n	October $\bar{x}$	October ±	October n
						Index square 4						
1947	--	--	0	79.3	2.4	6	82.1	1.1	10	80.3	1.4	3
1948	79.9	0.6	13	78.1	2.0	9	82.2	1.4	6	81.9	1.0	9
1949	80.0	2.0	8	80.0	7.4	3	81.7	3.8	3	80.9	1.2	9
1950	80.1	0.9	10	77.3	2.1	14	82.3	0.5	16	80.6	1.0	12
1951	79.9	1.0	10	80.1	1.1	16	84.0	0.8	12	84.2	0.7	13
1952	80.3	3.2	10	80.0	2.5	11	82.9	0.8	15	82.9	1.3	11
1953	81.5	0.8	11	81.1	1.4	14	83.2	1.5	10	82.7	1.8	6
1954	78.5	2.2	17	78.9	2.4	14	78.6	3.3	12	80.3	2.6	9
1955	78.7	3.7	7	78.4	4.1	5	81.7	2.1	13	81.5	0.8	16
1956	78.7	1.9	10	76.9	2.2	14	83.2	1.7	10	81.1	1.0	15
1957	80.1	1.4	10	79.1	0.9	21	84.5	1.1	13	83.6	0.9	19
1958	81.1	1.2	16	82.6	1.0	18	83.6	0.9	18	83.7	0.8	21
1947-58 (unweighted)	79.9	0.6	11	79.3	1.0	12	82.5	1.0	12	82.0	0.9	12
						Index square 5						
1947	--	--	0	75.9	2.2	8	71.2	2.2	5	74.3	0.9	6
1948	78.2	2.8	6	78.7	2.9	3	73.5	6.4	2	72.8	1.6	5
1949	78.0	1.2	6	73.0	12.7	2	--	--	0	70.4	3.4	8
1950	76.8	5.7	4	71.3	10.3	3	70.6	2.3	7	73.1	1.8	9
1951	78.7	1.1	6	70.5	3.2	5	79.0	2.2	9	75.0	6.8	6
1952	79.0	0.0	2	73.2	4.5	6	67.6	2.6	26	71.4	0.9	20
1953	77.3	2.7	4	82.0	25.4	2	75.5	31.8	2	68.5	1.4	10
1954	71.5	3.4	11	70.3	3.9	11	67.9	4.4	9	70.4	1.3	31
1955	75.5	4.8	4	--	--	0	71.7	3.8	3	71.3	4.3	10
1956	75.5	1.5	15	74.8	6.0	4	74.9	2.7	8	69.8	2.2	13
1957	73.5	8.4	4	80.2	4.4	6	78.0	38.1	2	72.8	2.6	12
1958	76.9	1.4	17	78.8	1.0	31	72.2	2.8	10	75.0	0.8	36
1947-58 (unweighted)	76.4	1.5	11	75.3	2.8	11	72.9	2.5	11	72.1	1.3	12

*Presence of gross errors in source data.

PART I

SEA SURFACE TEMPERATURE MONTHLY AVERAGE CHARTS

EASTERN TROPICAL PACIFIC OCEAN, 1947-58

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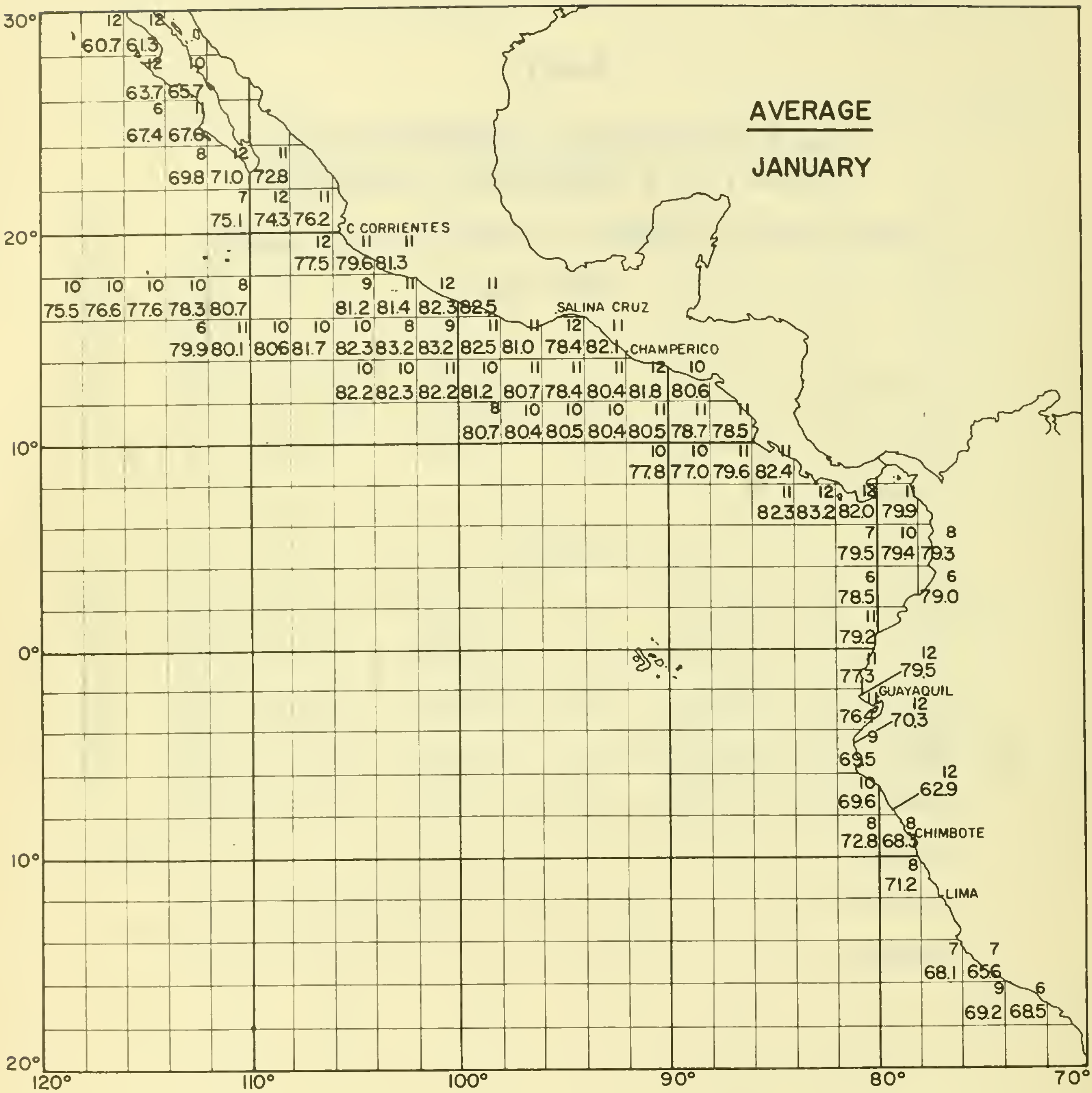
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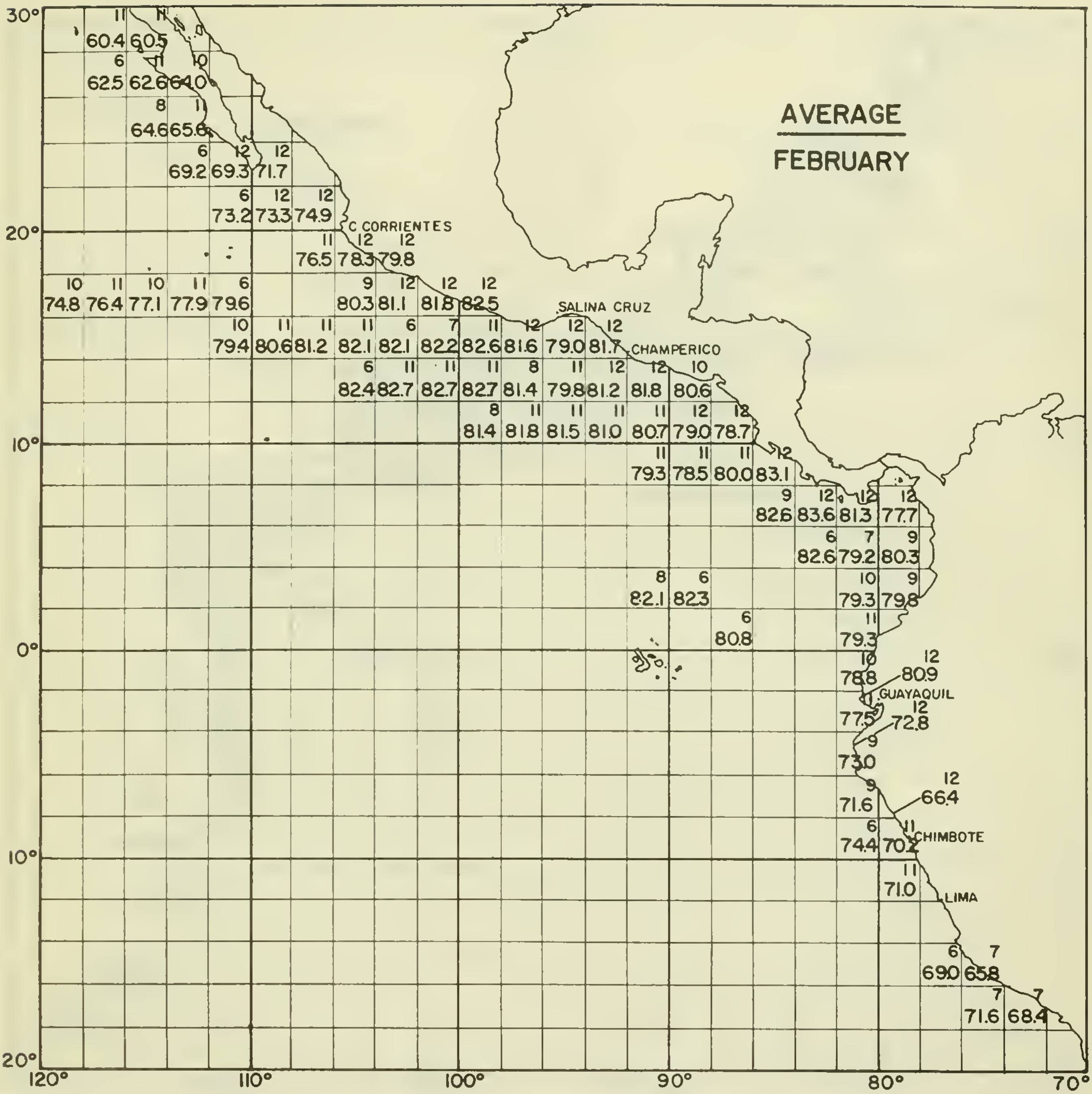
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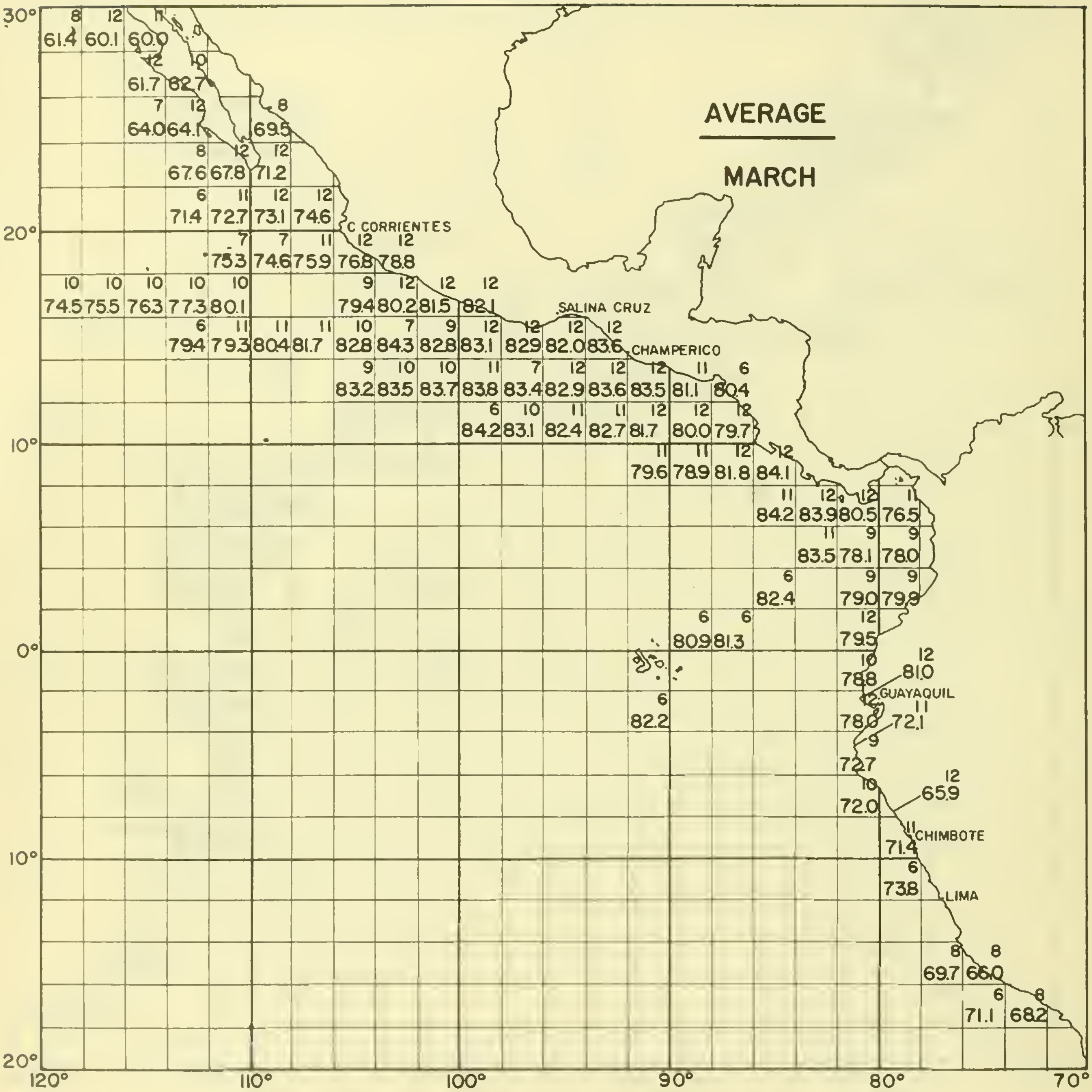
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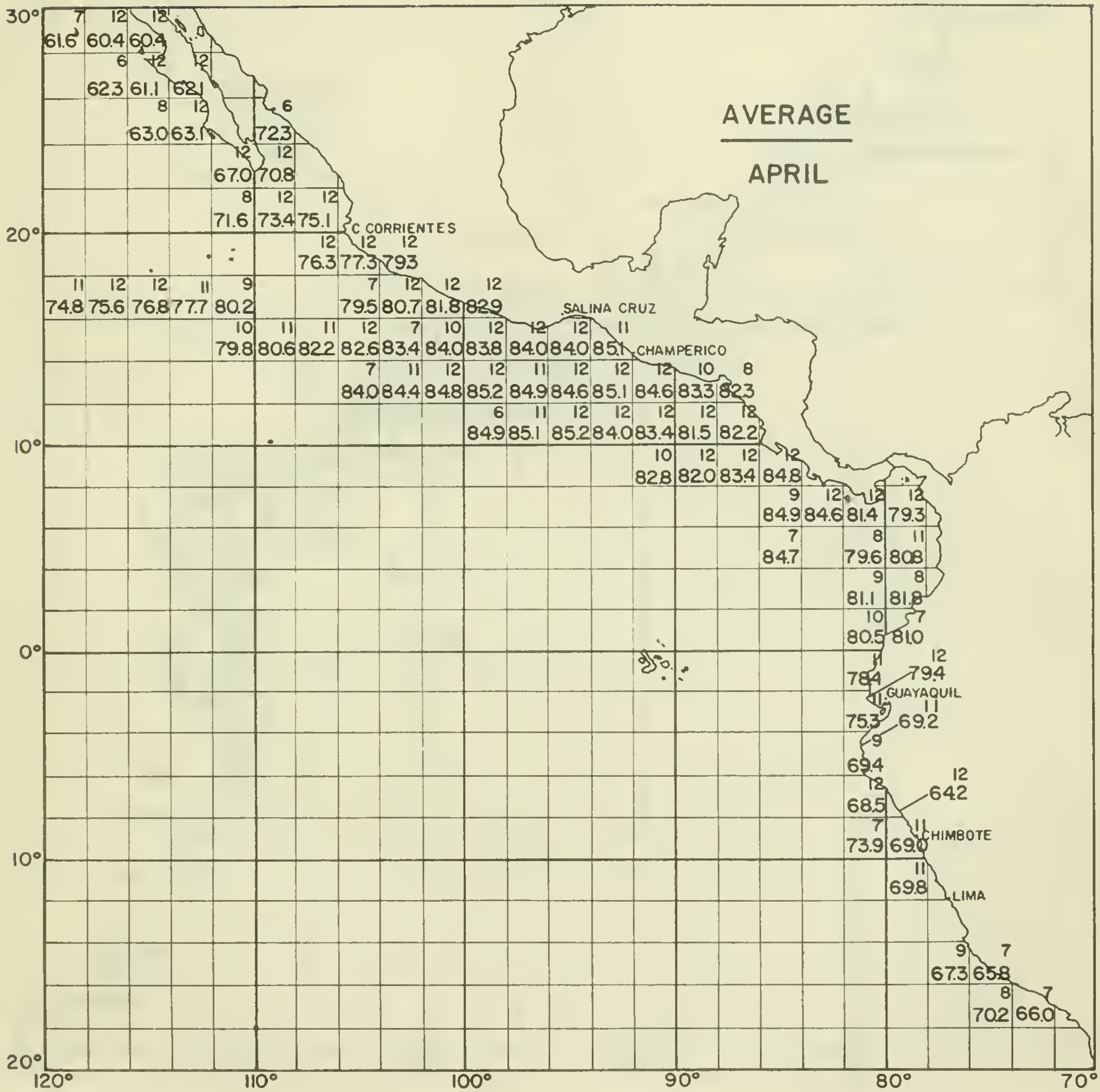
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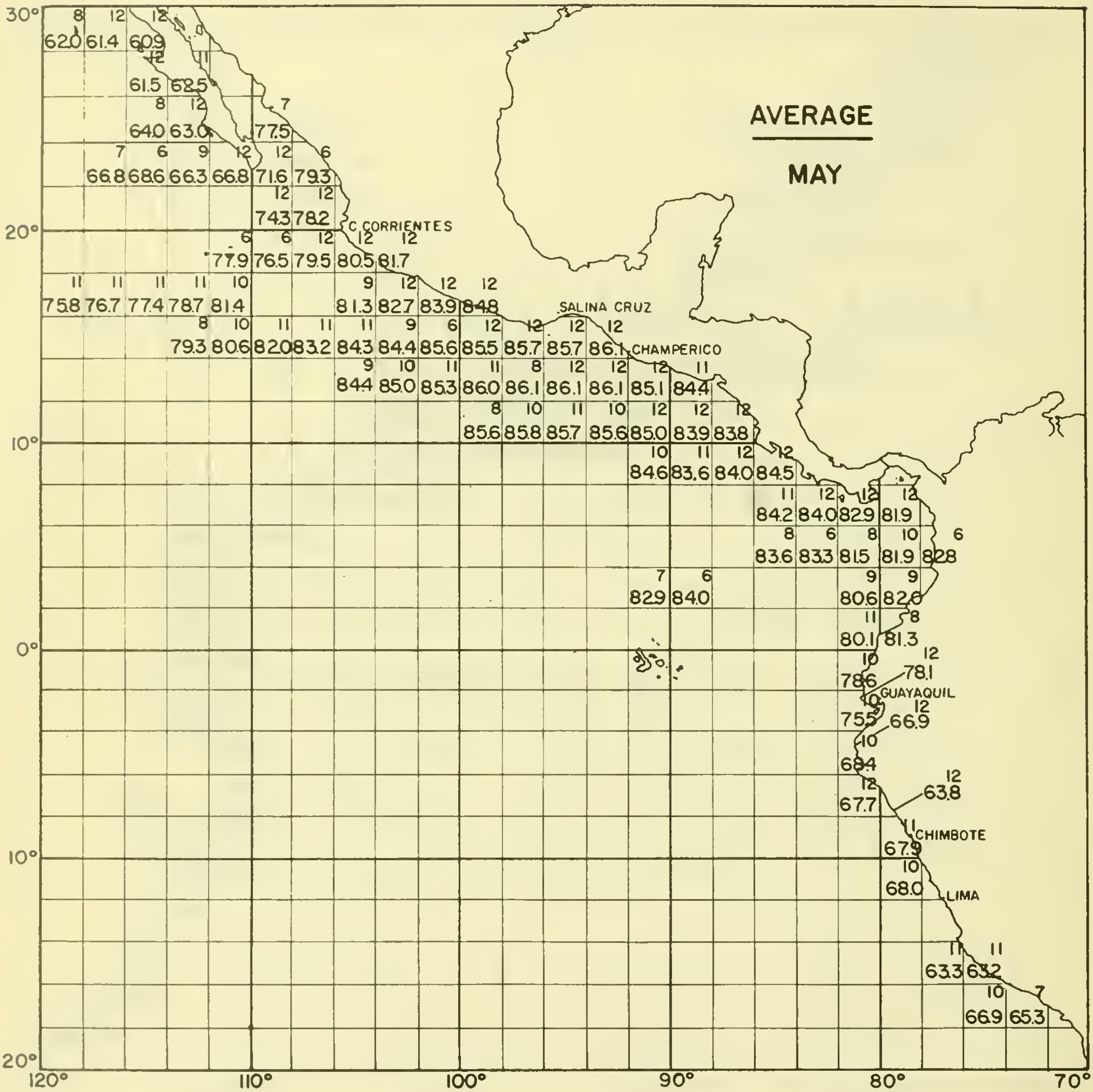
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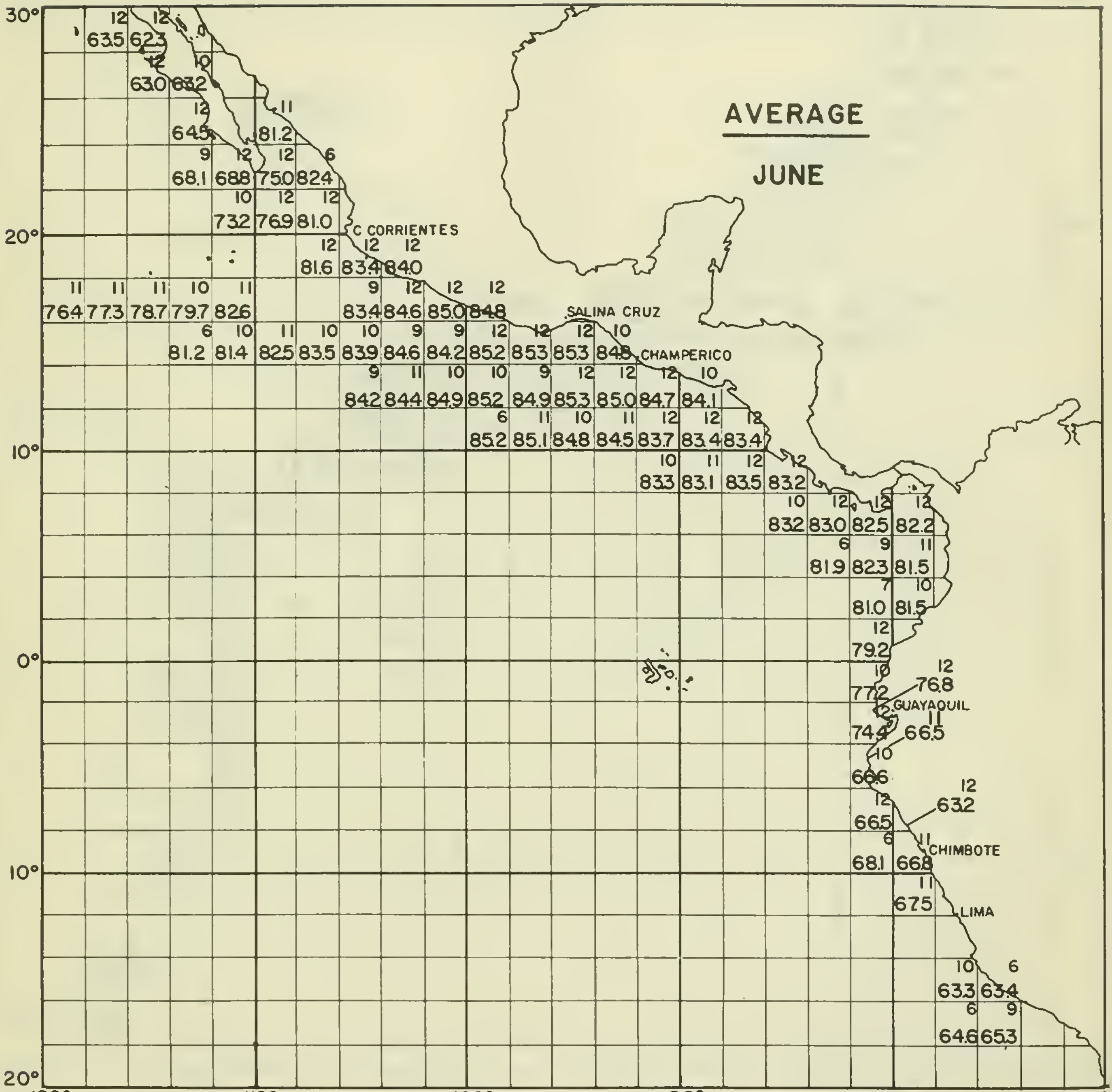
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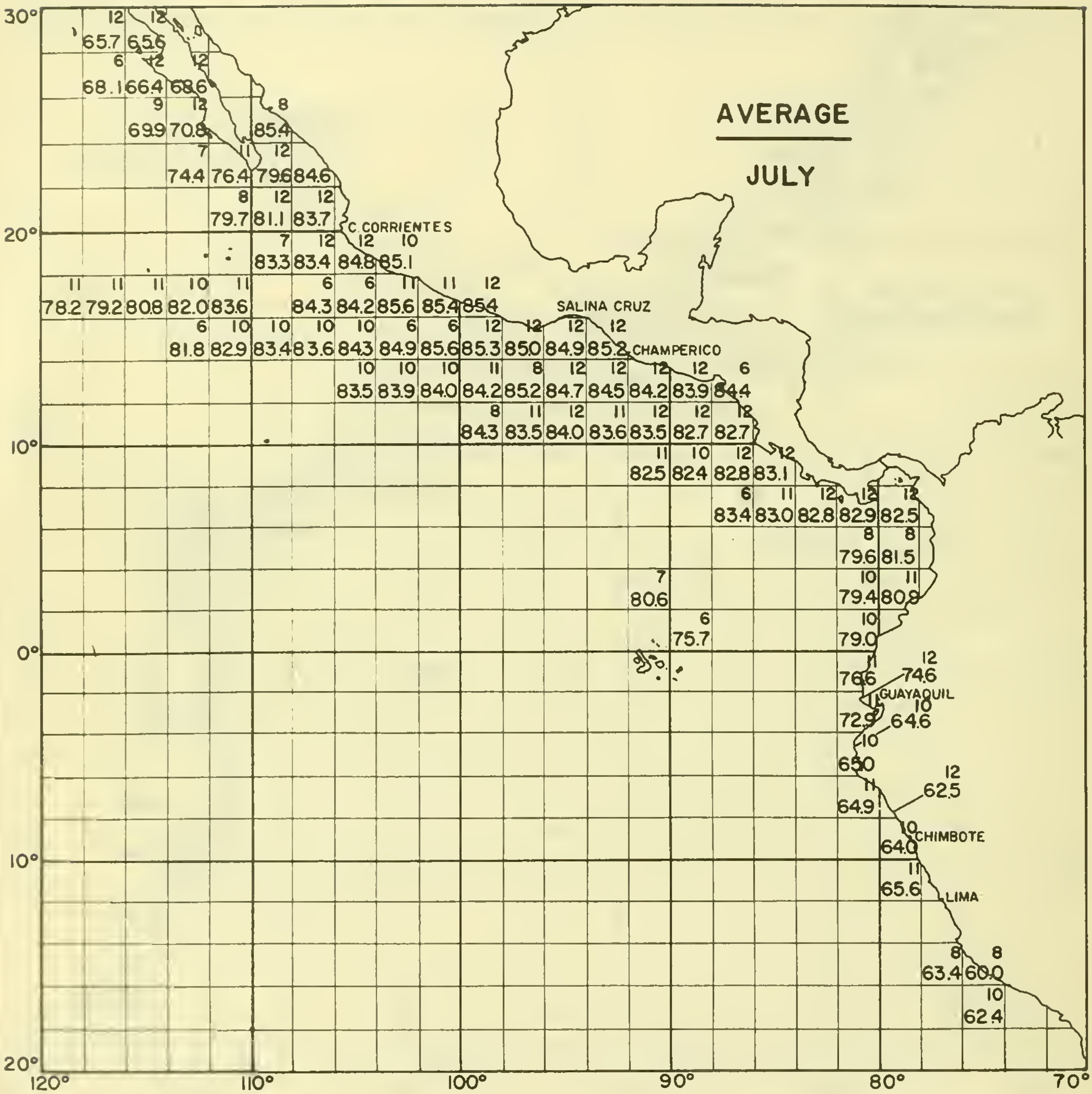

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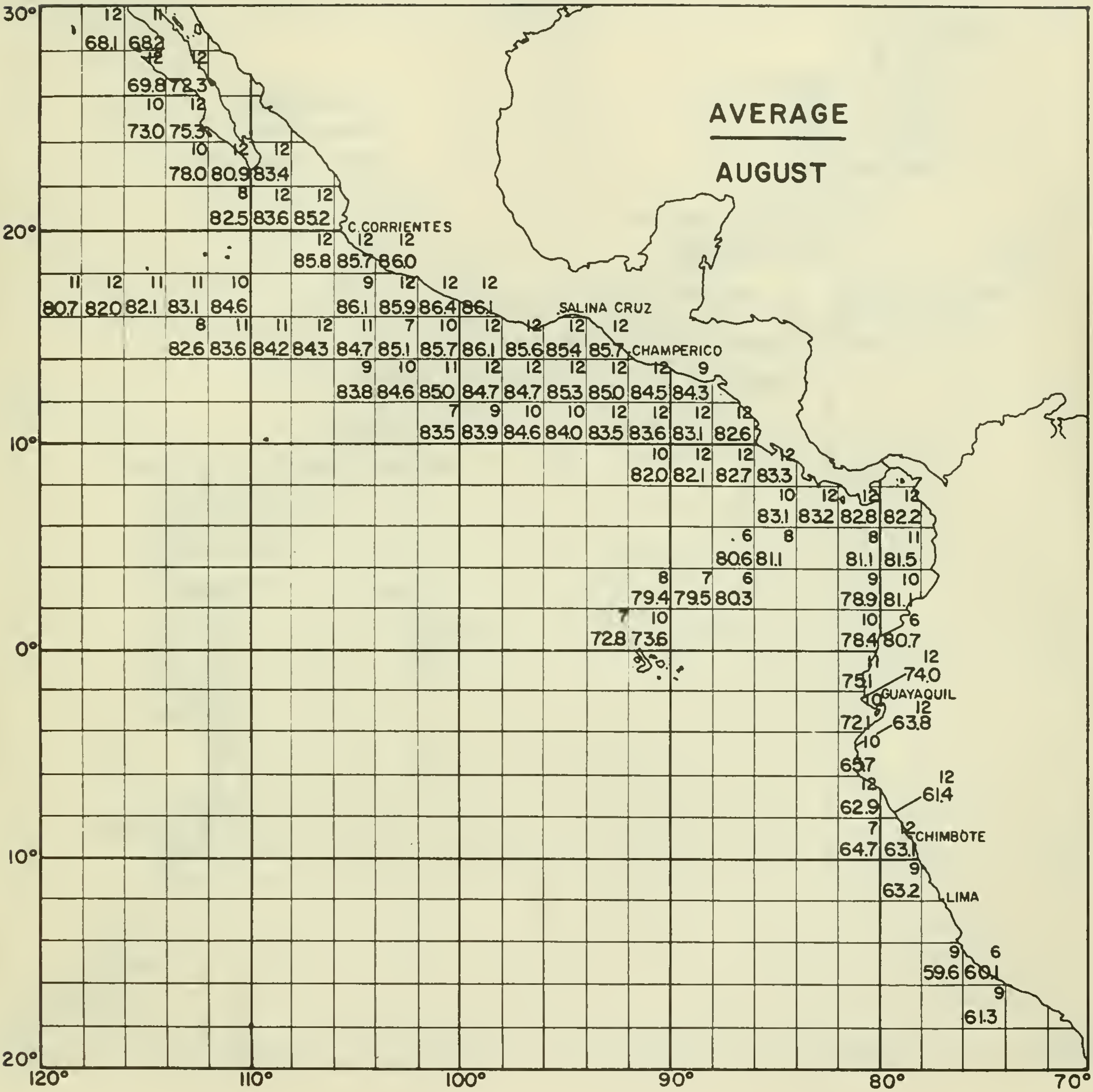
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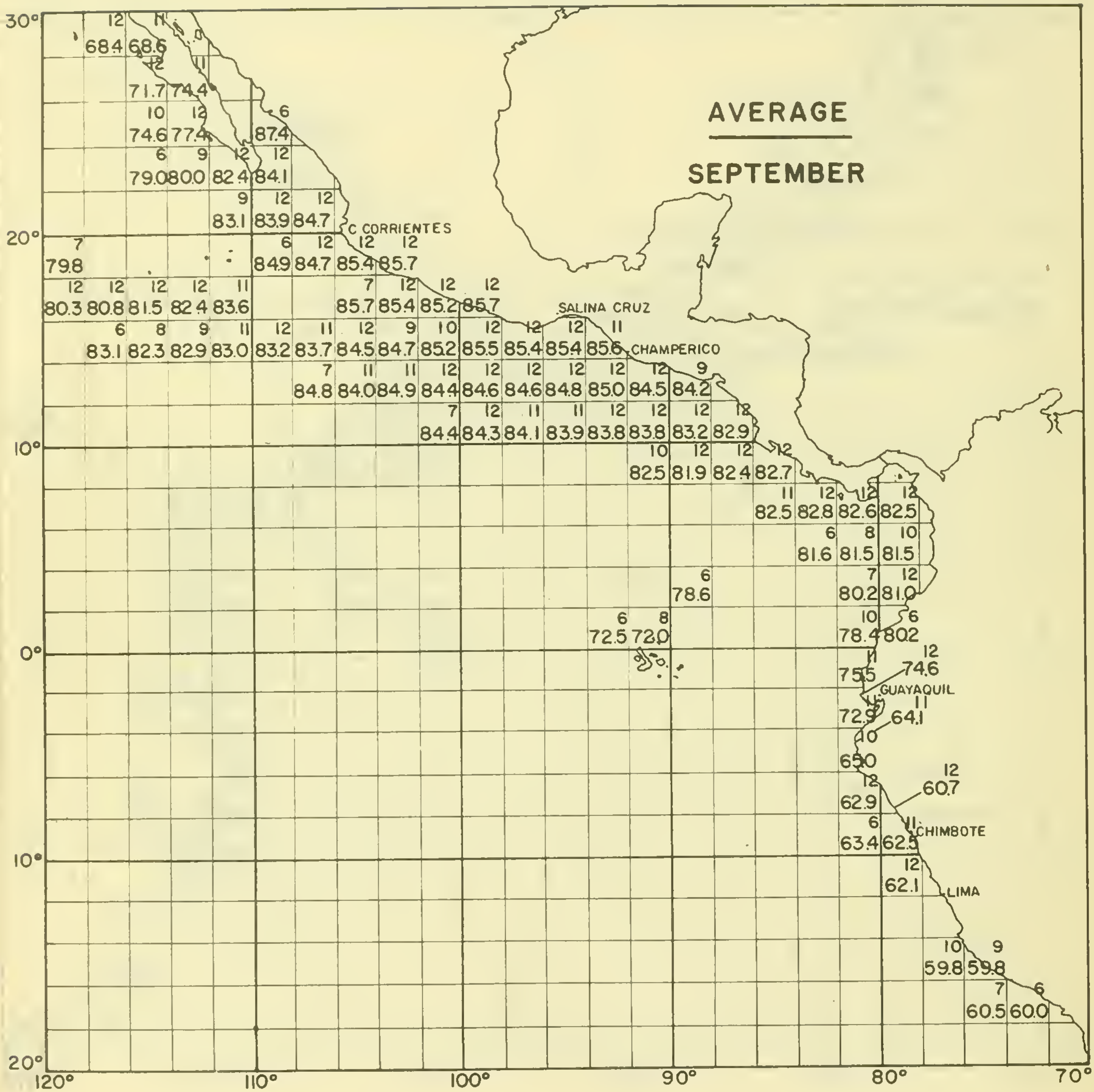
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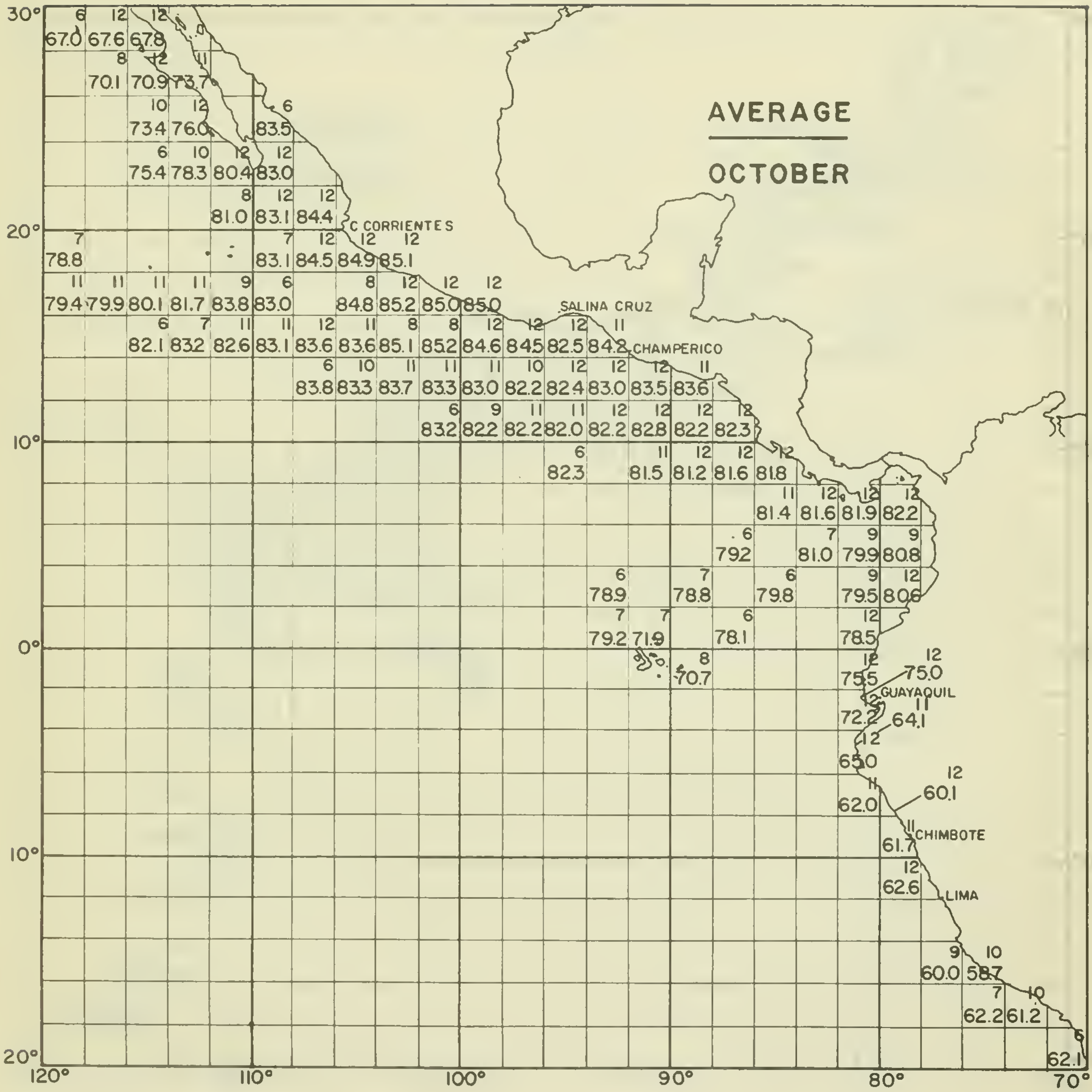
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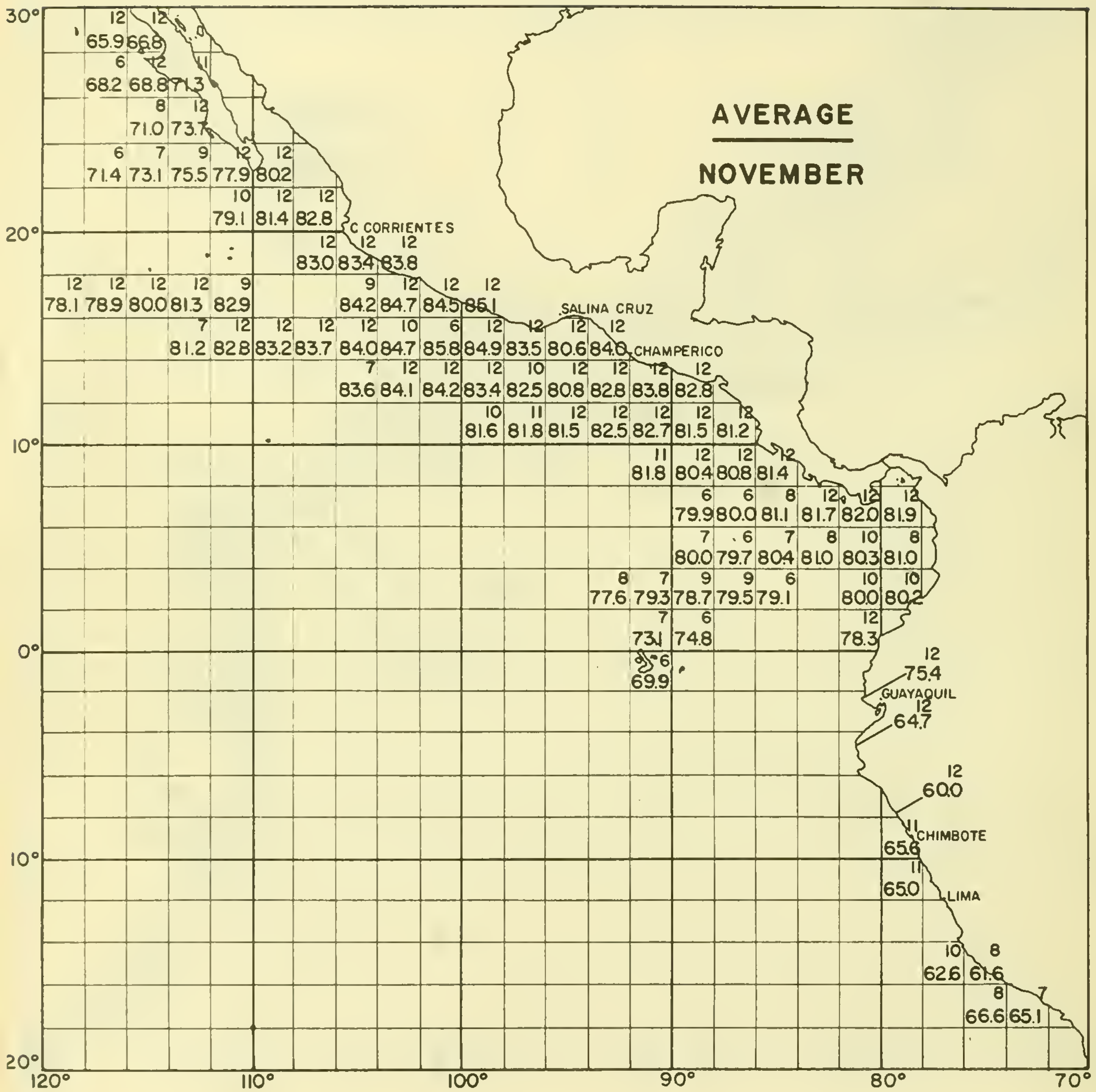
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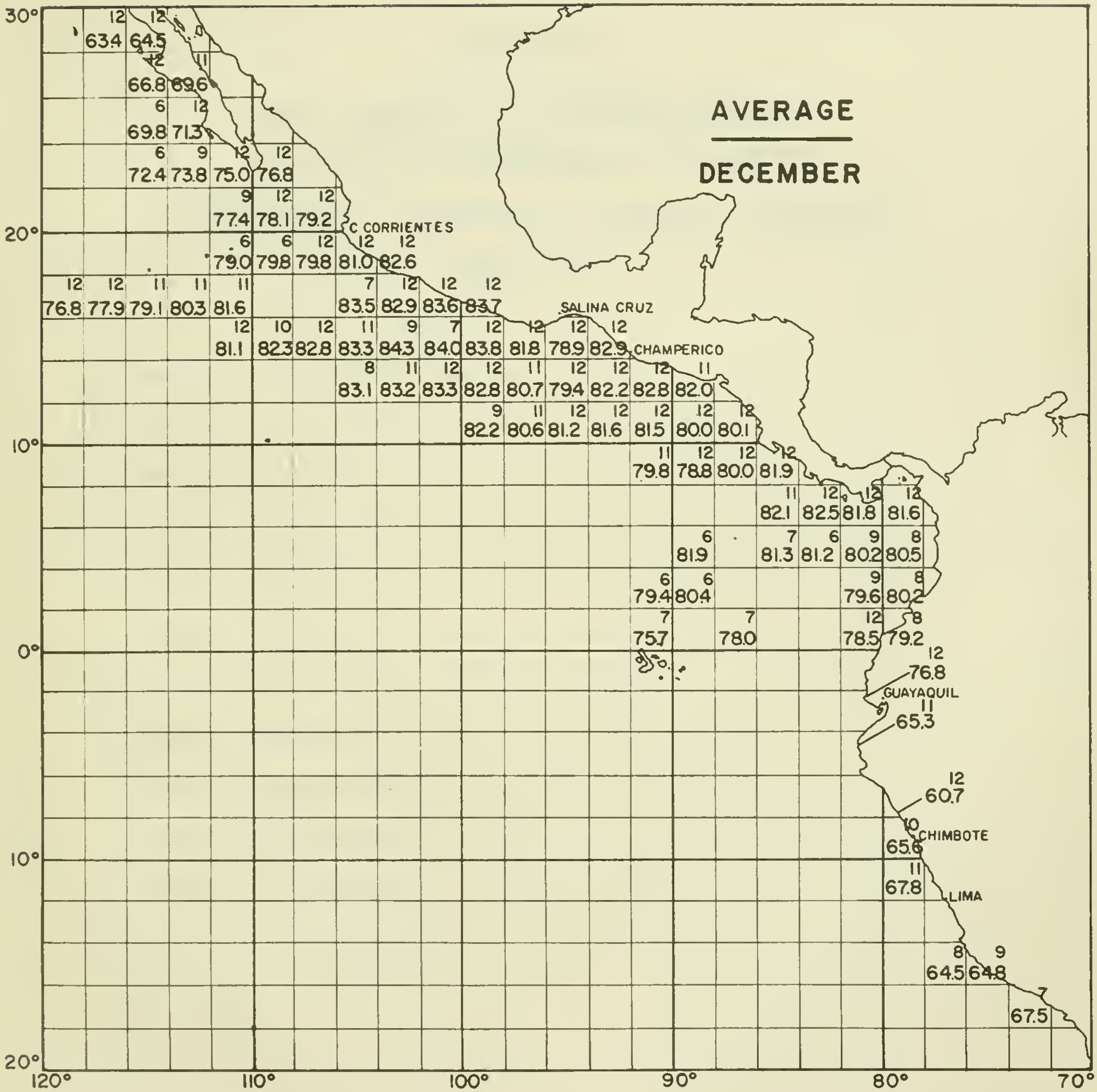
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PART II

SEA SURFACE TEMPERATURE MONTHLY ANOMALY CHARTS

EASTERN TROPICAL PACIFIC OCEAN, 1947-58

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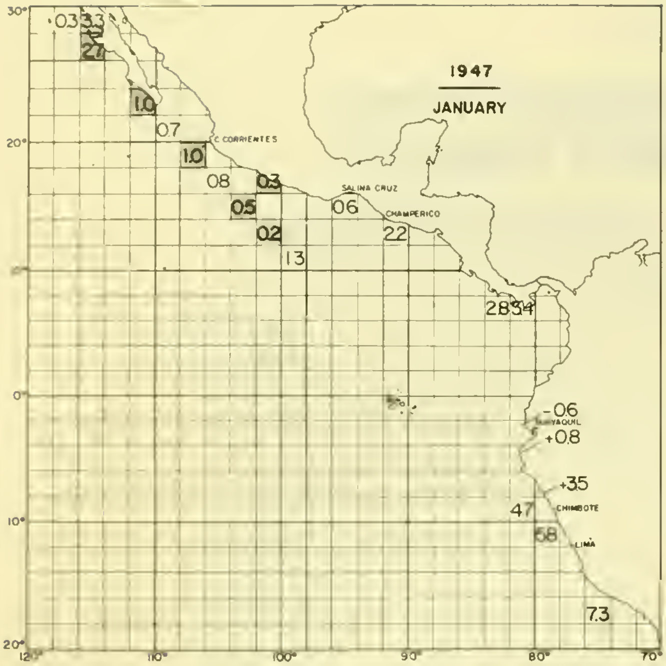
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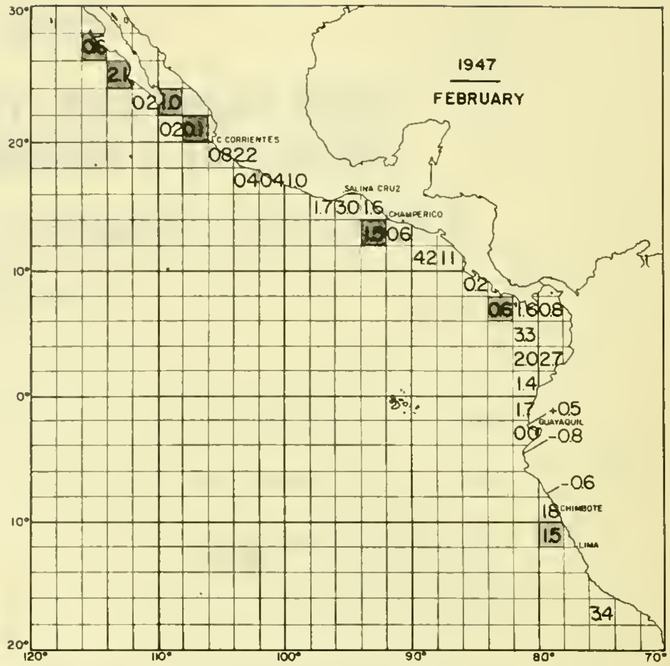
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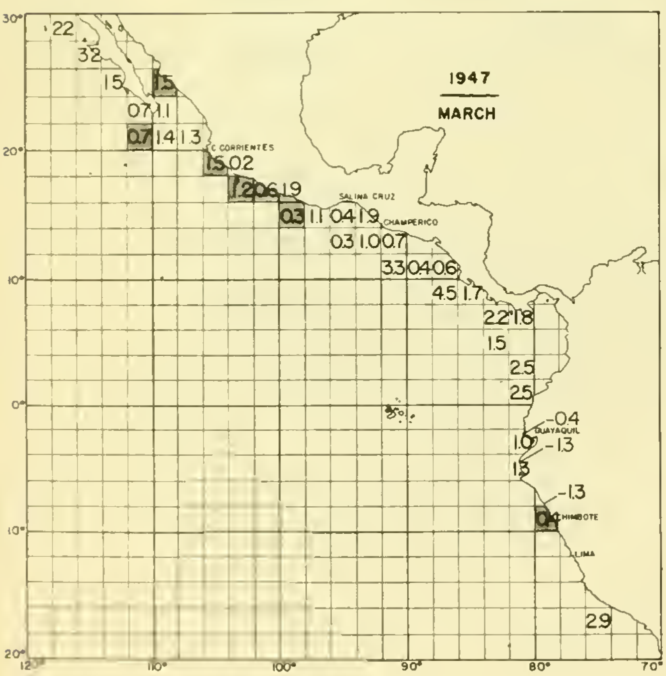
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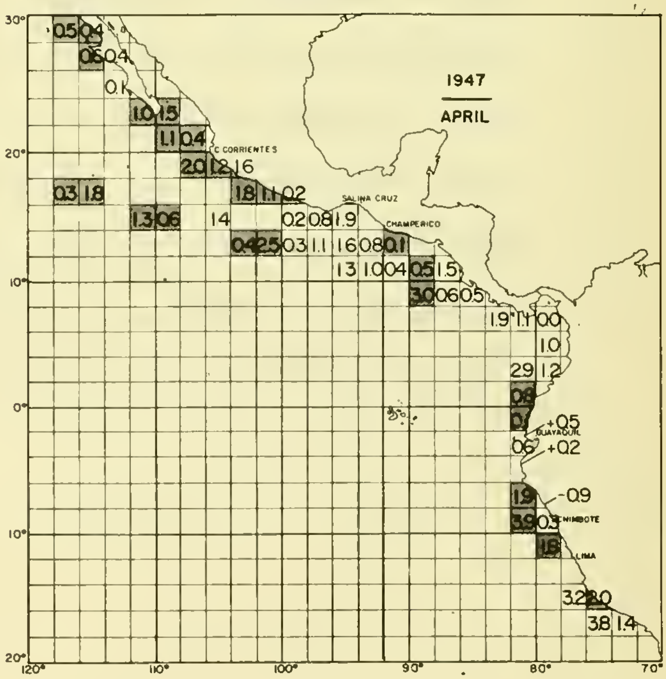
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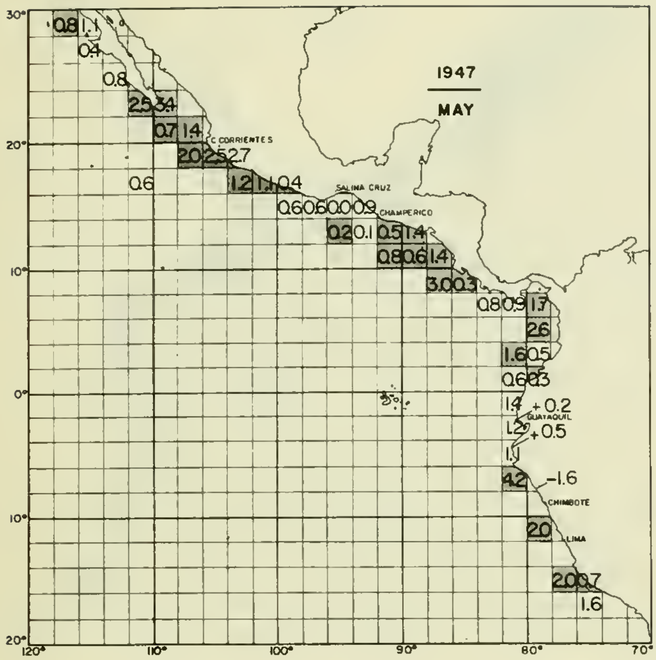
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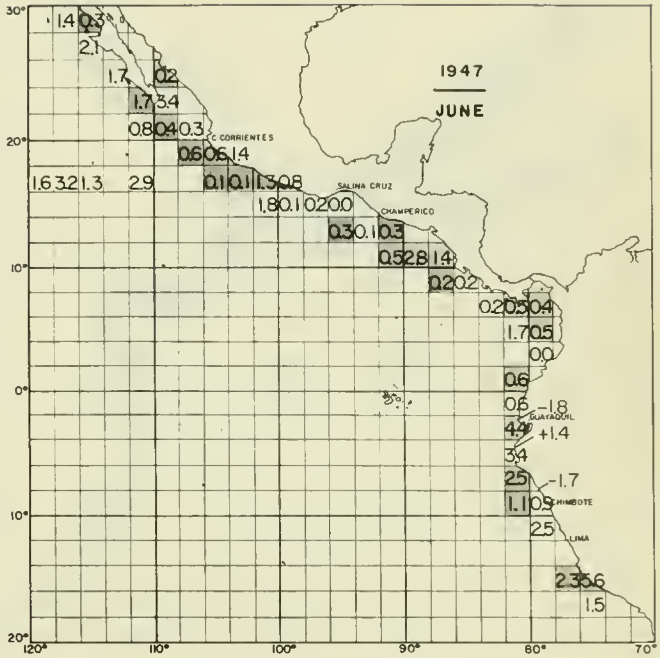
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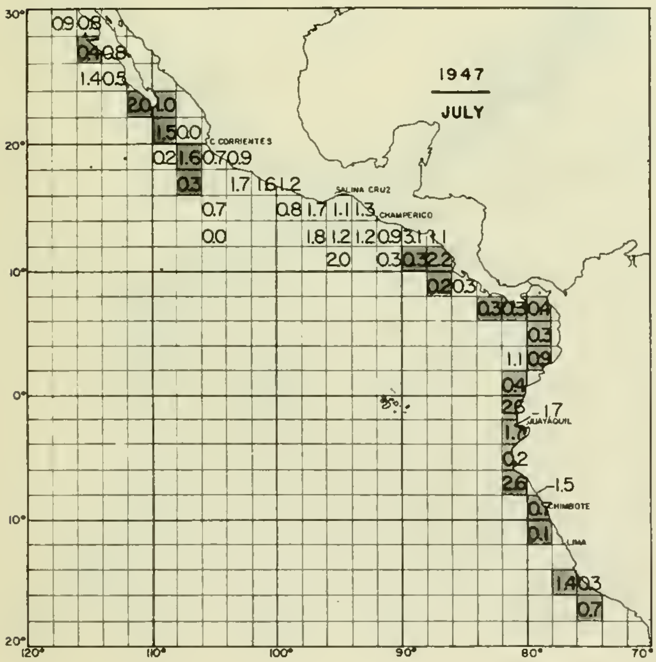
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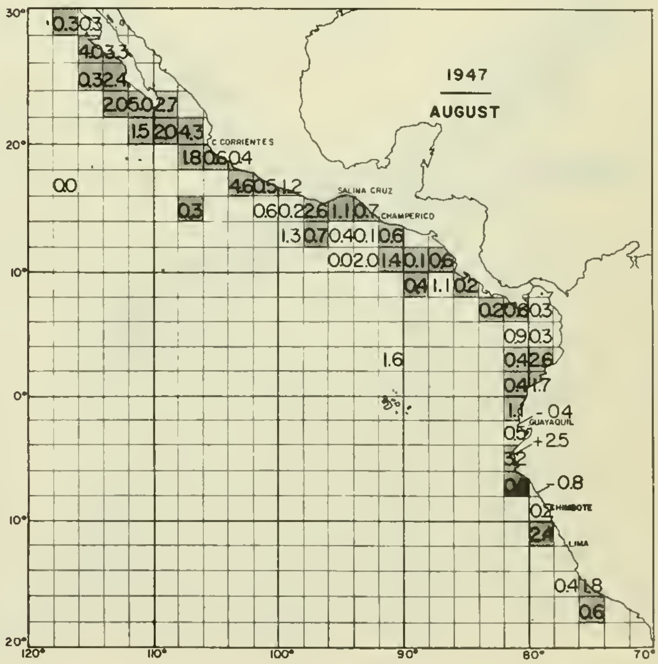
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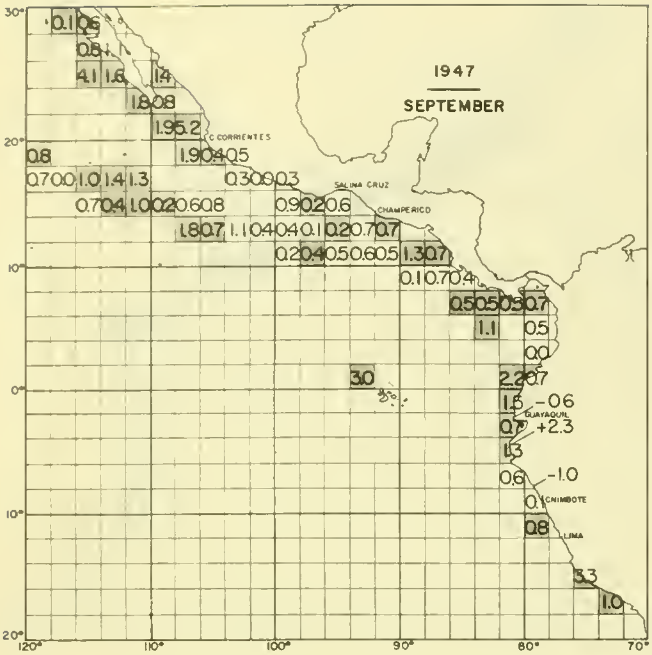
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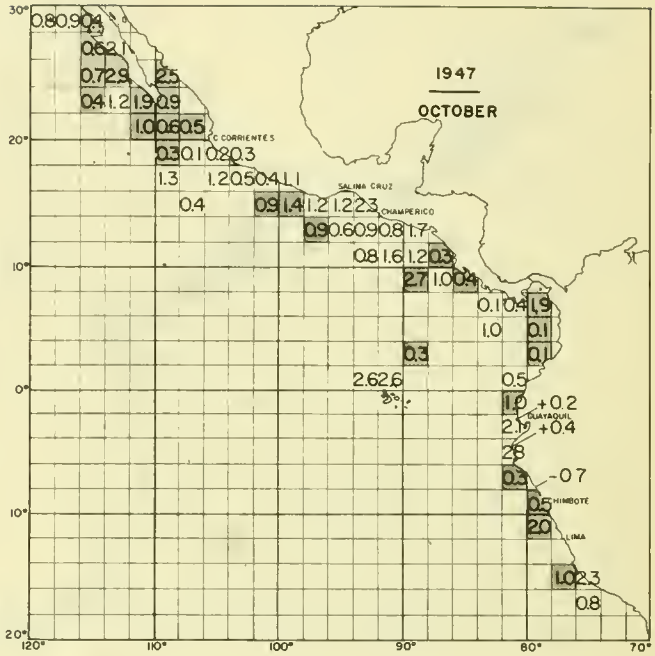
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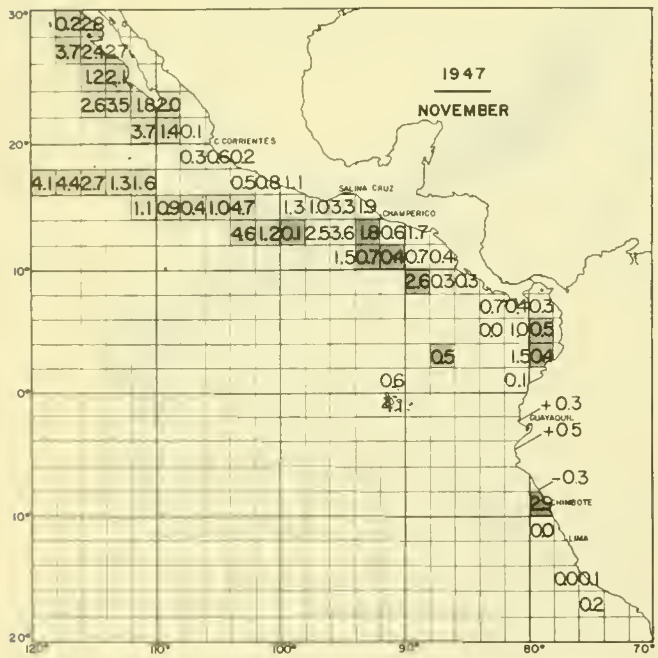
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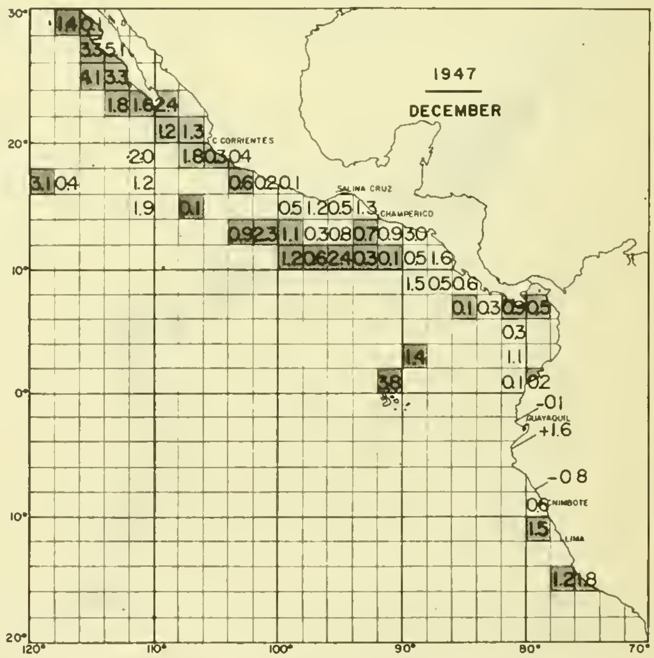
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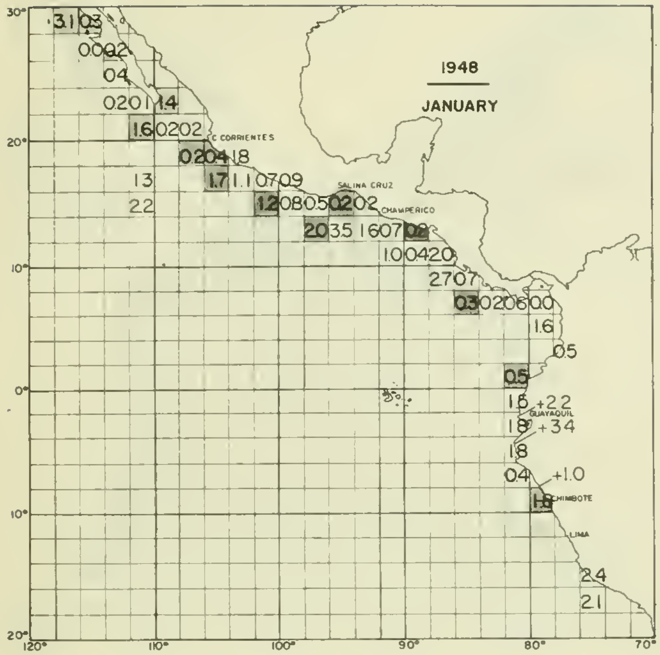
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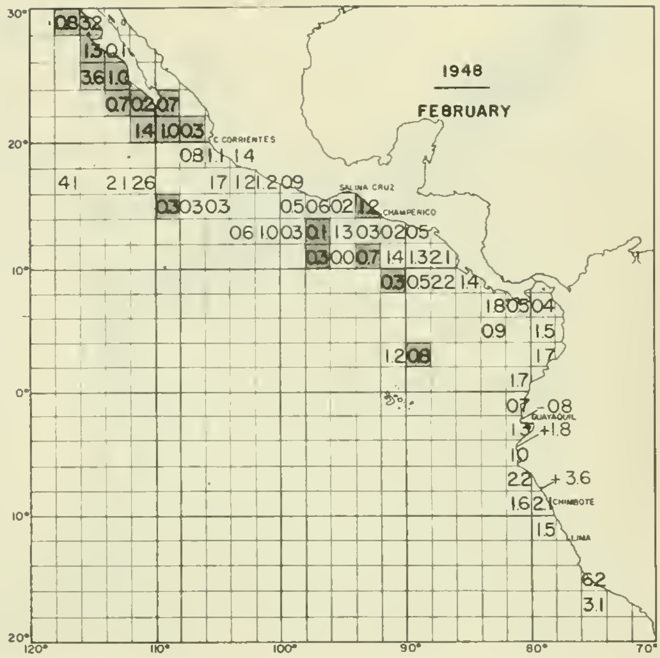
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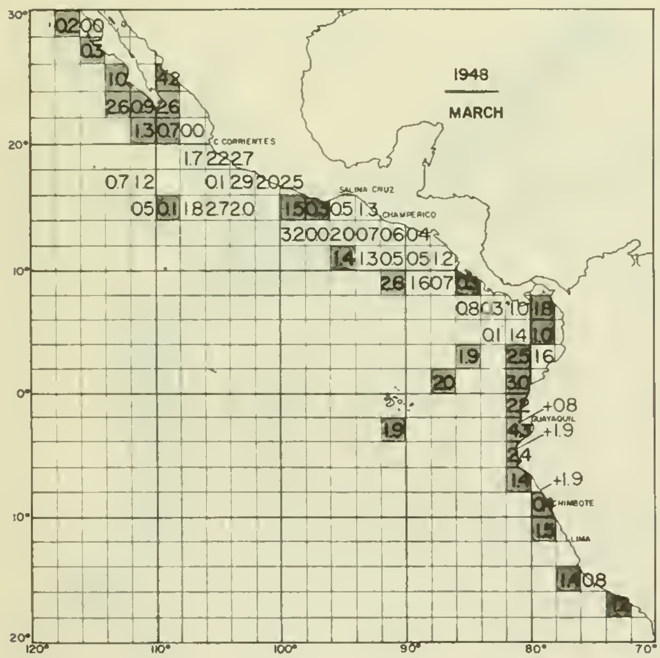
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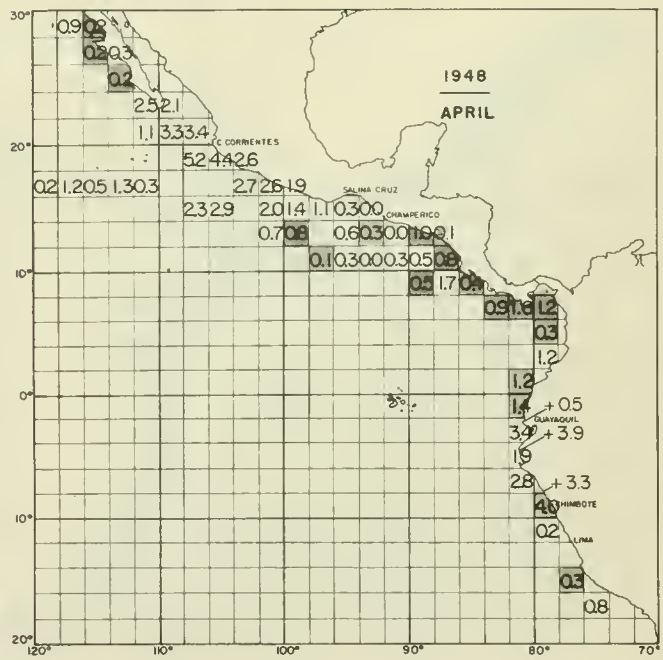
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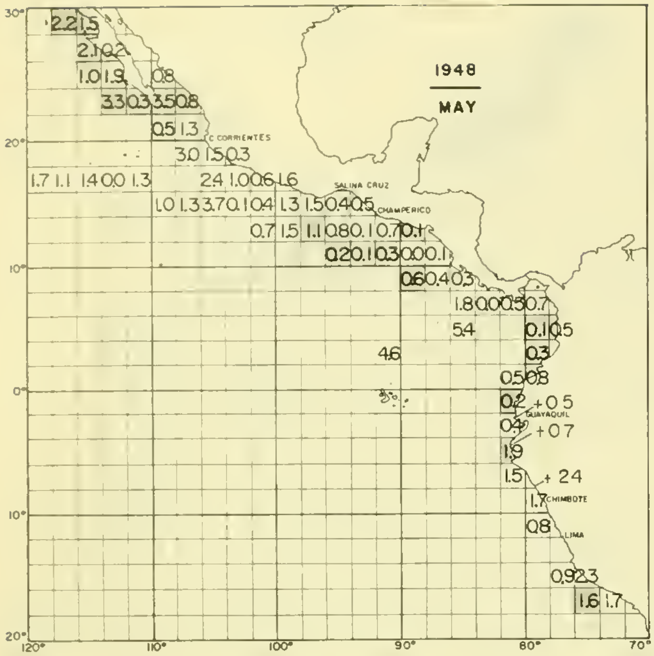
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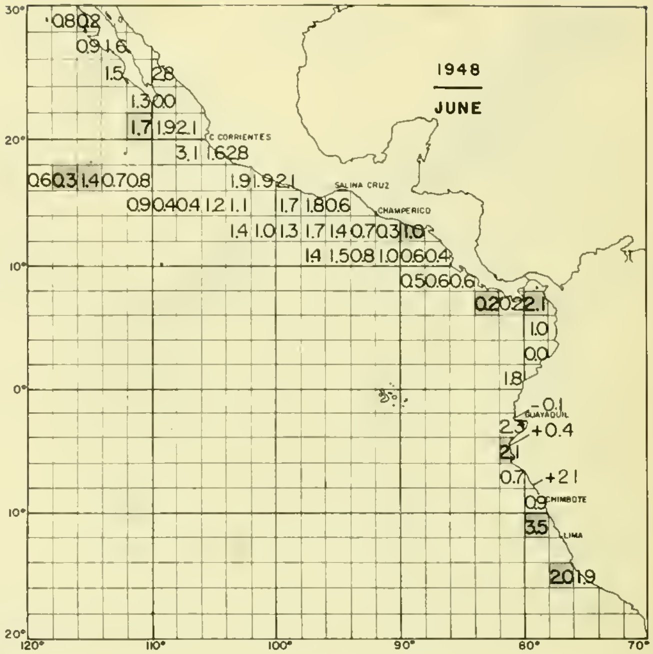
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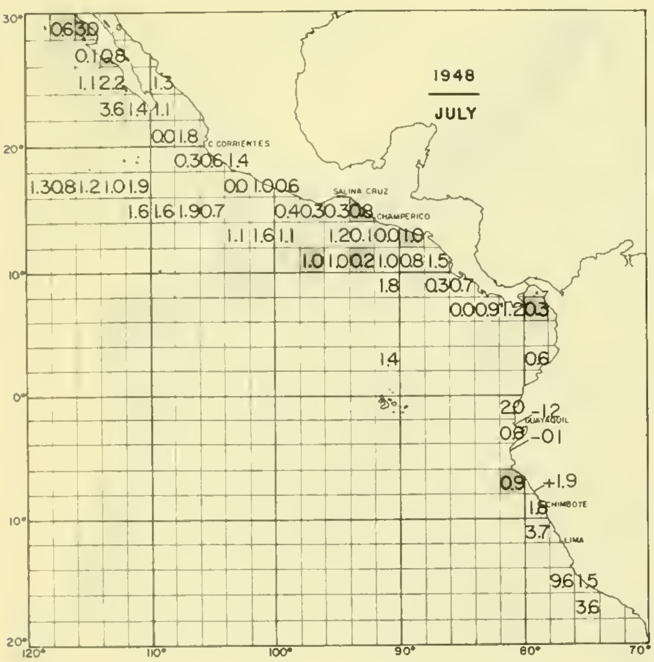
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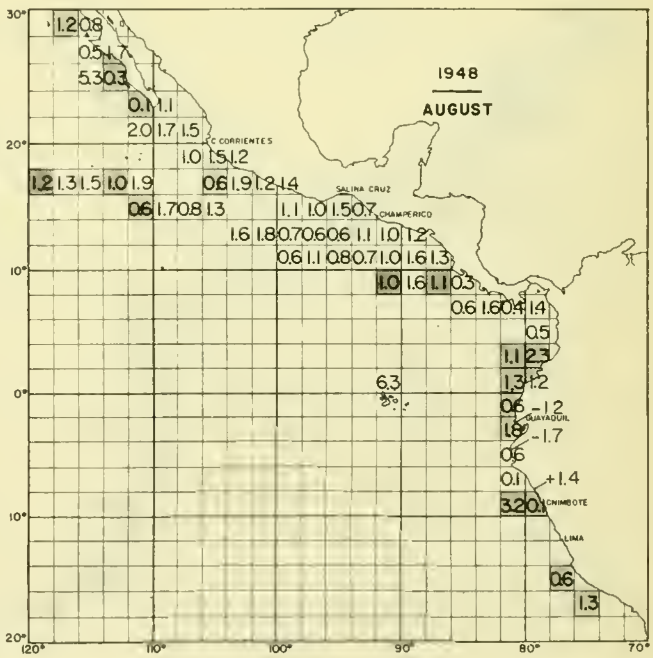
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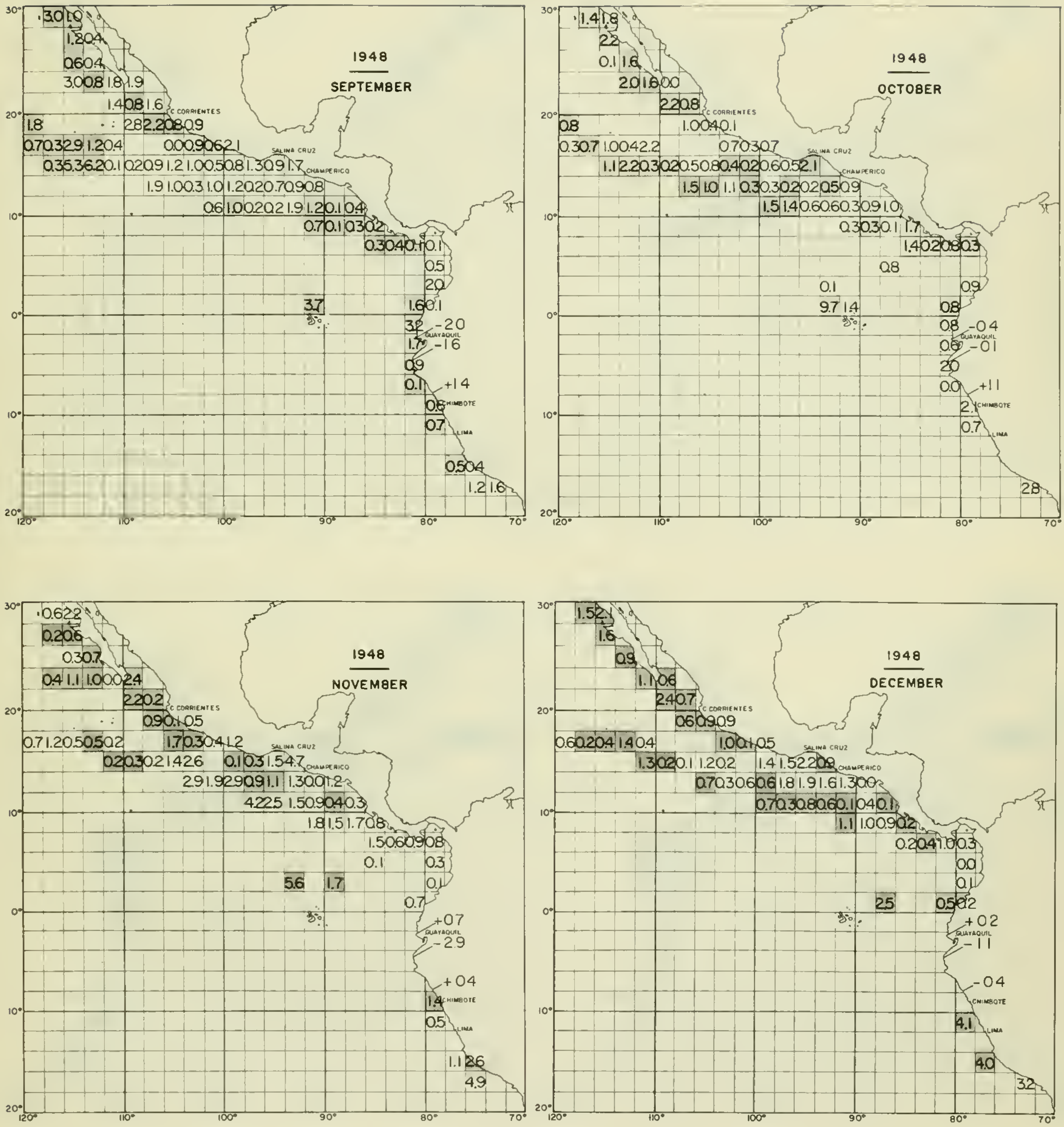
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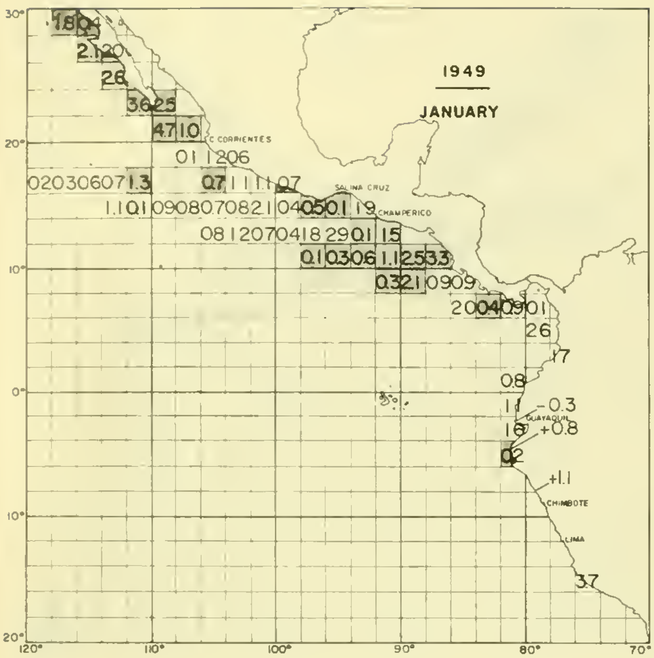
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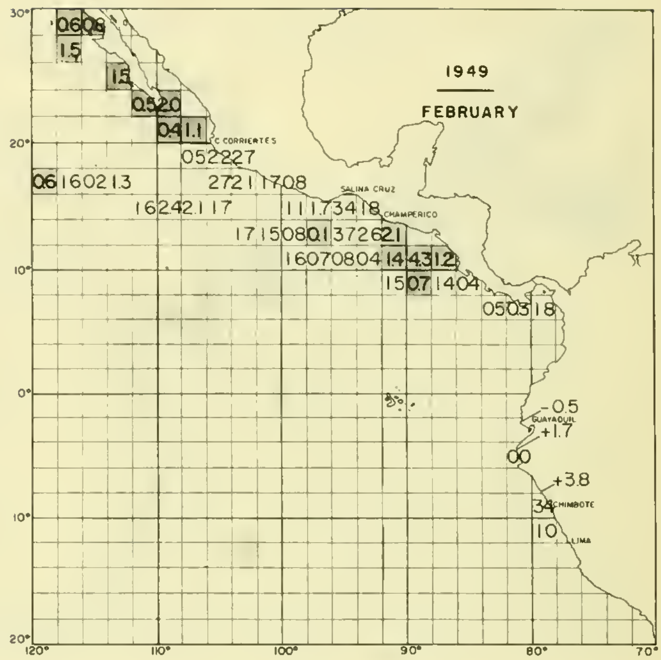
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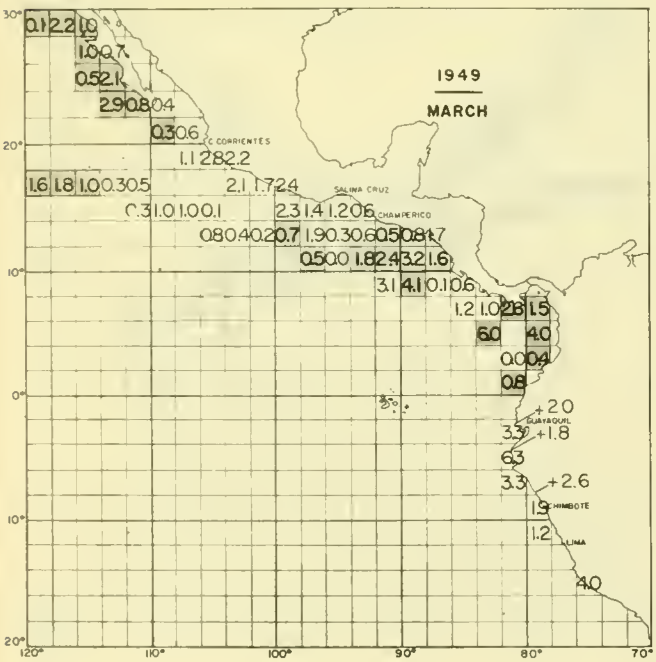
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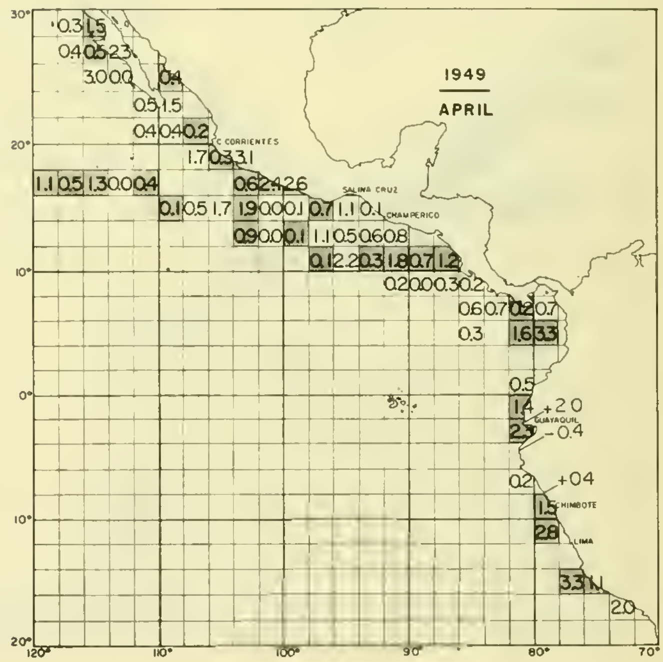
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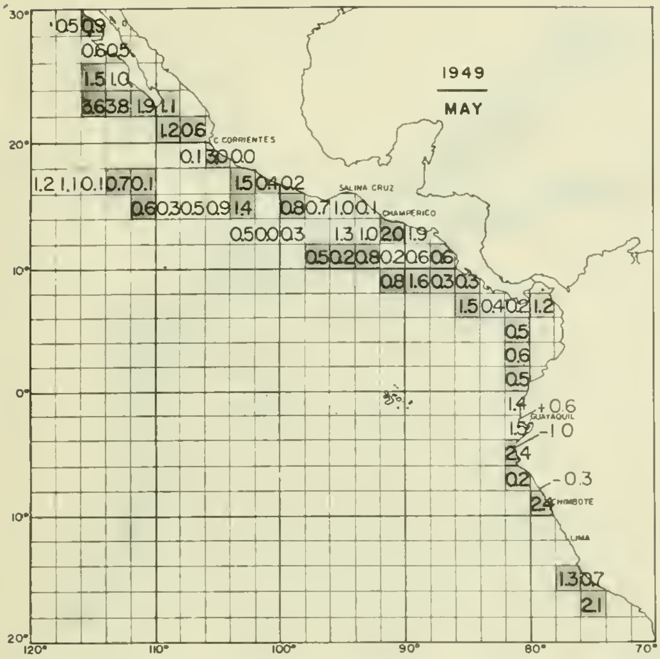
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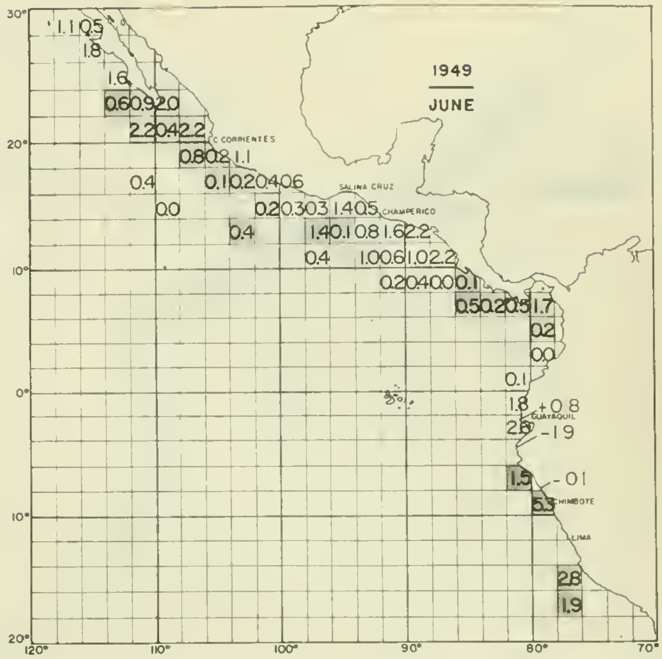
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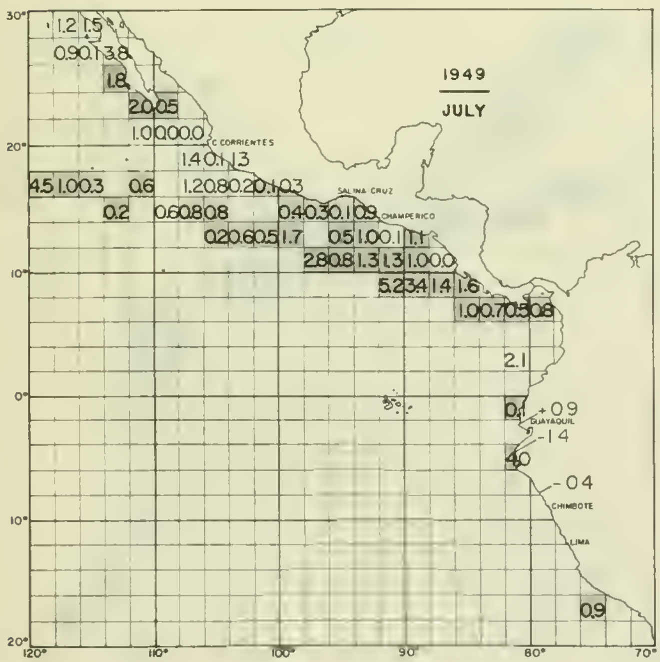
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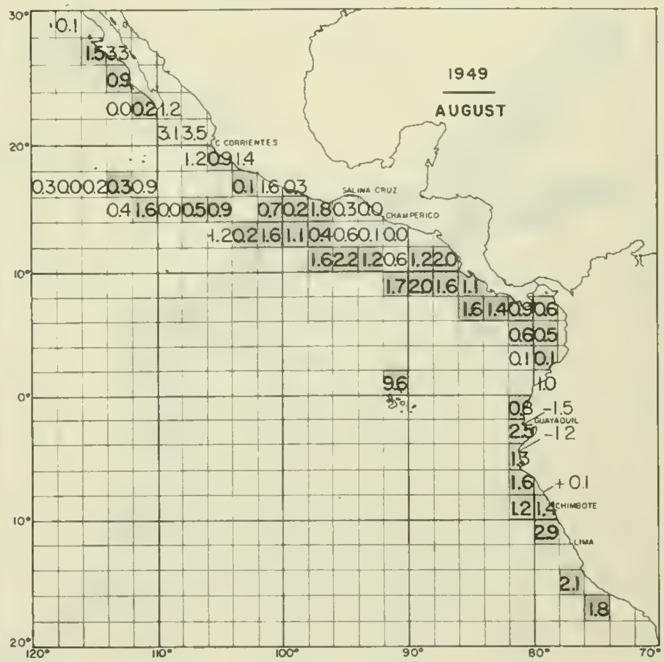
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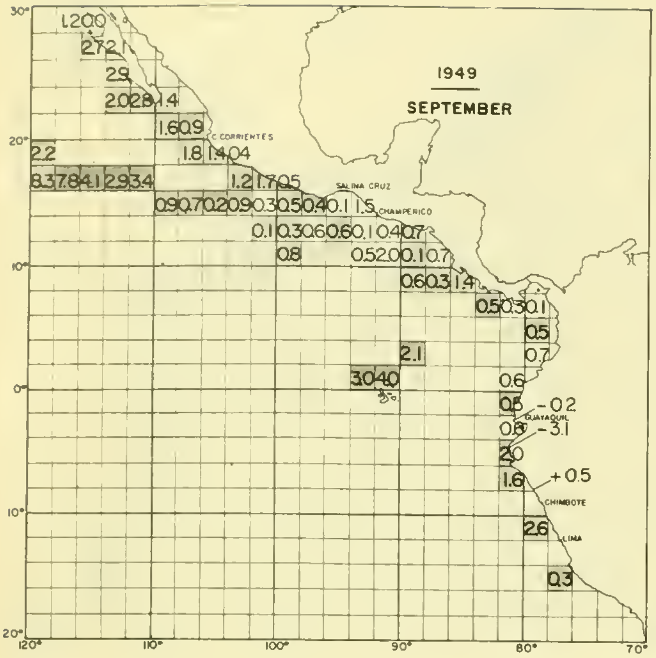
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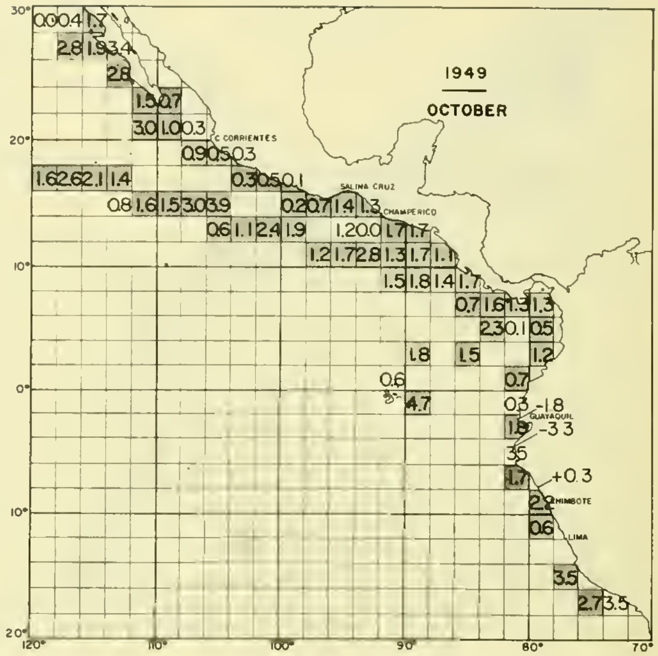
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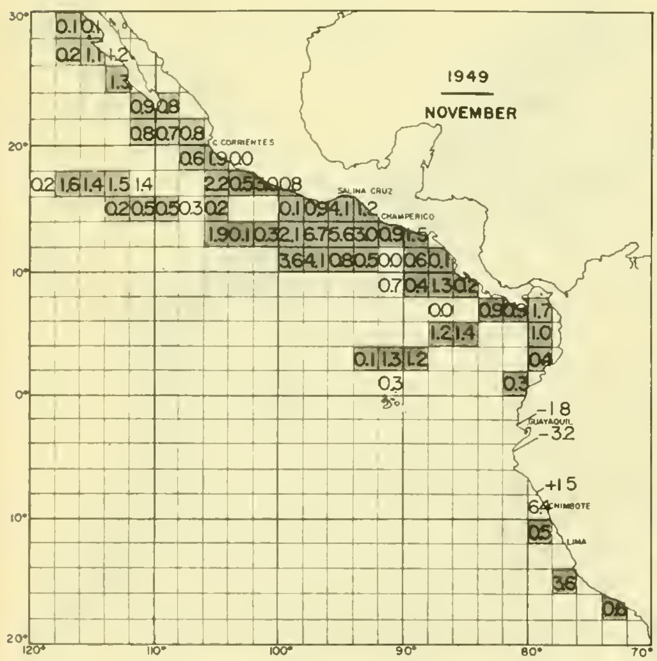
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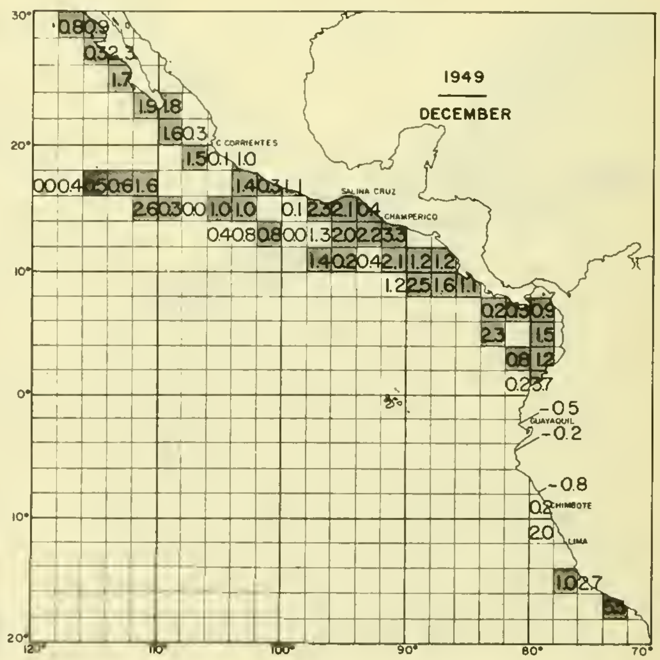
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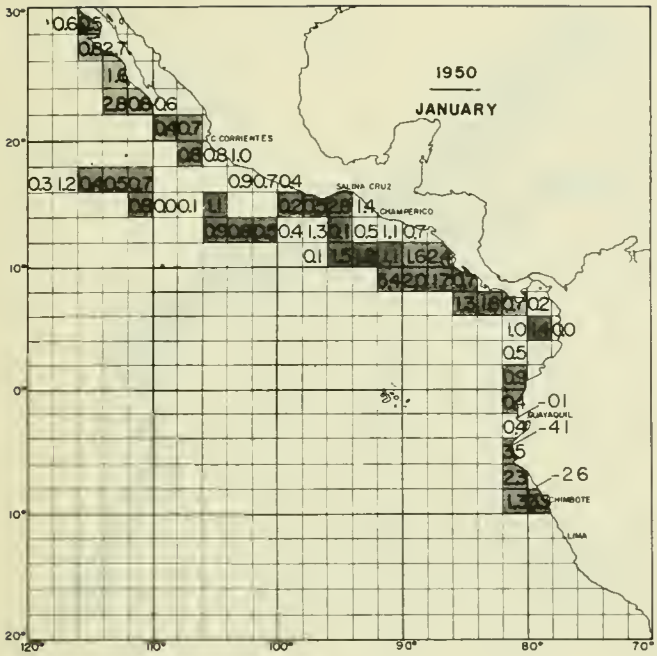
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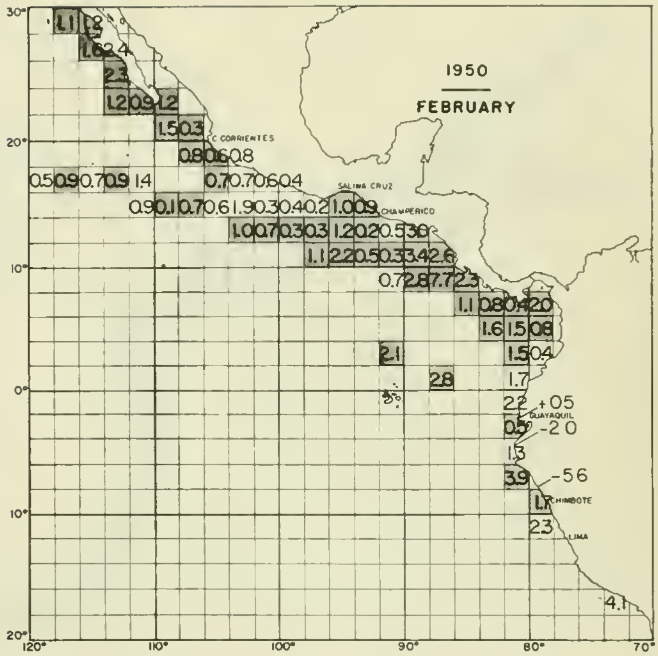
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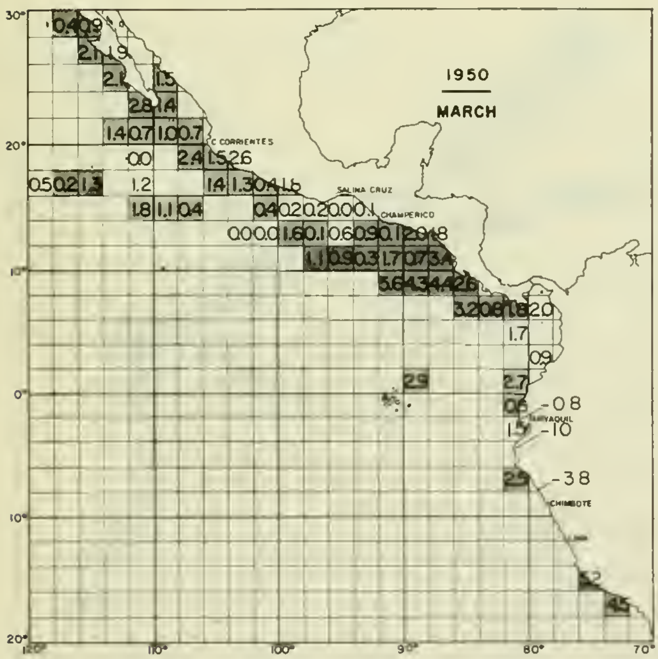
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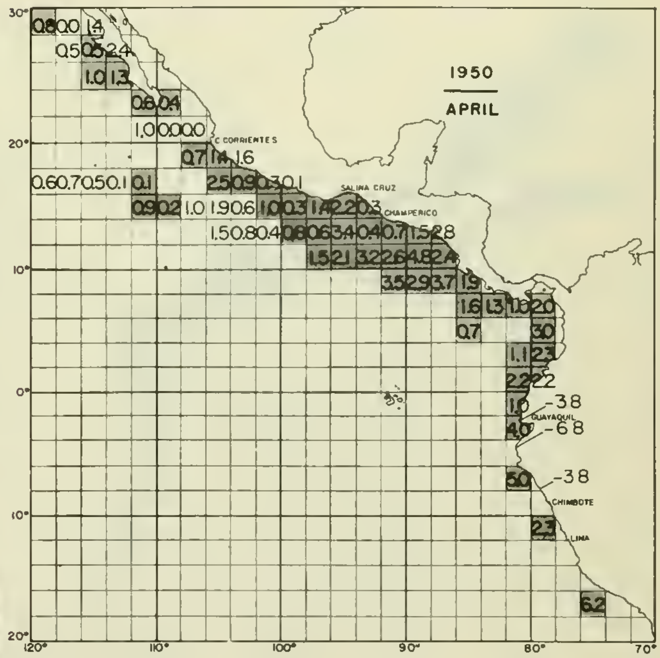
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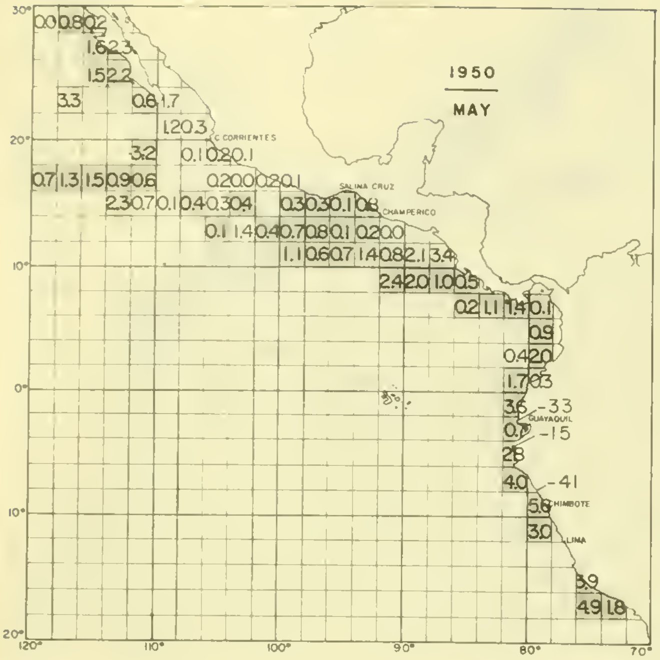
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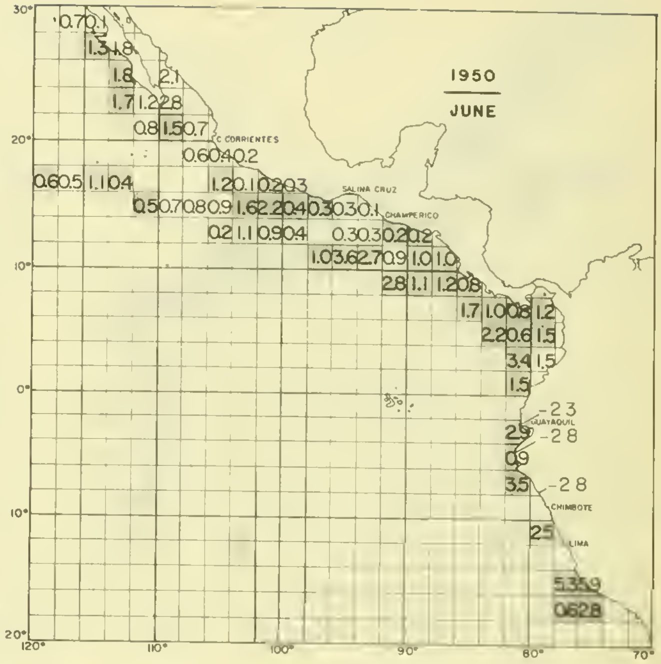
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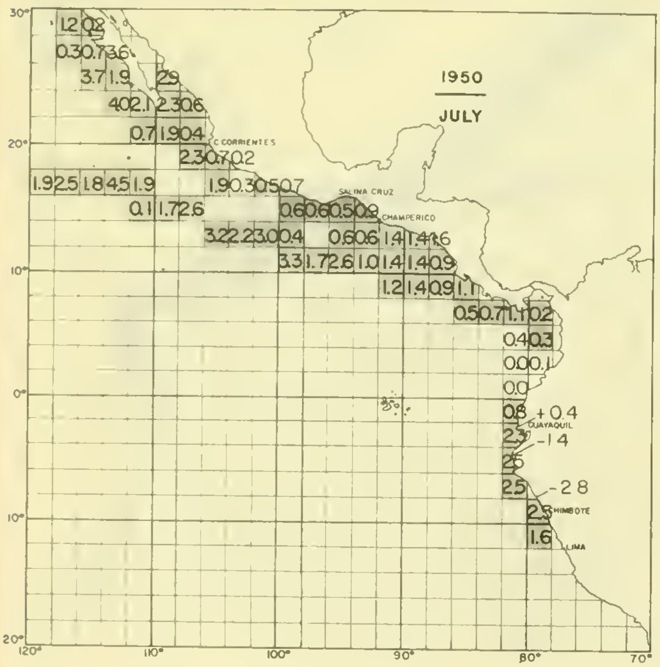
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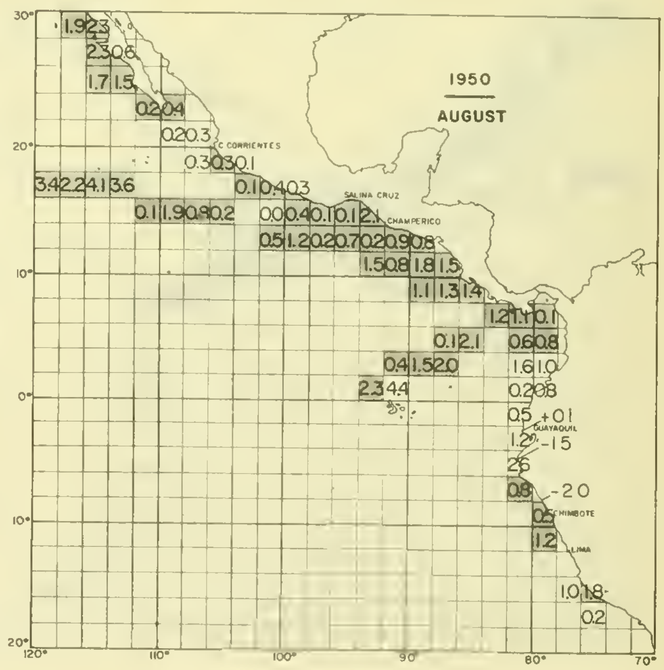
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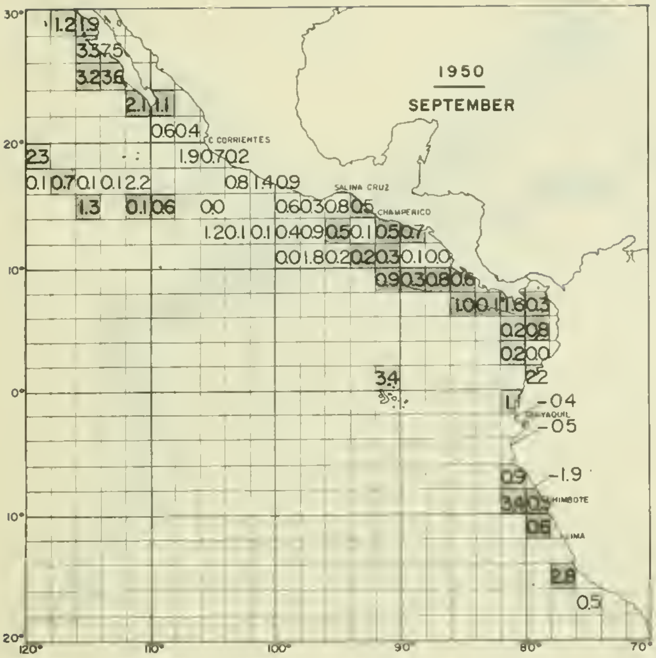
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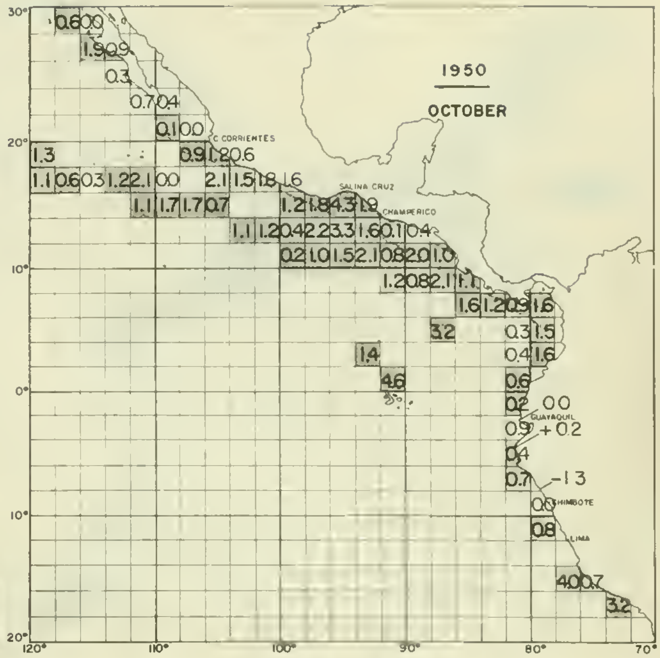
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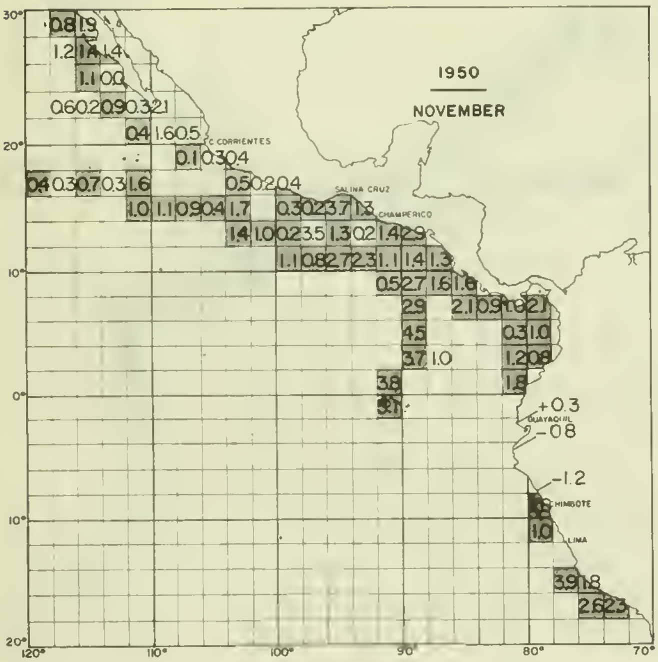
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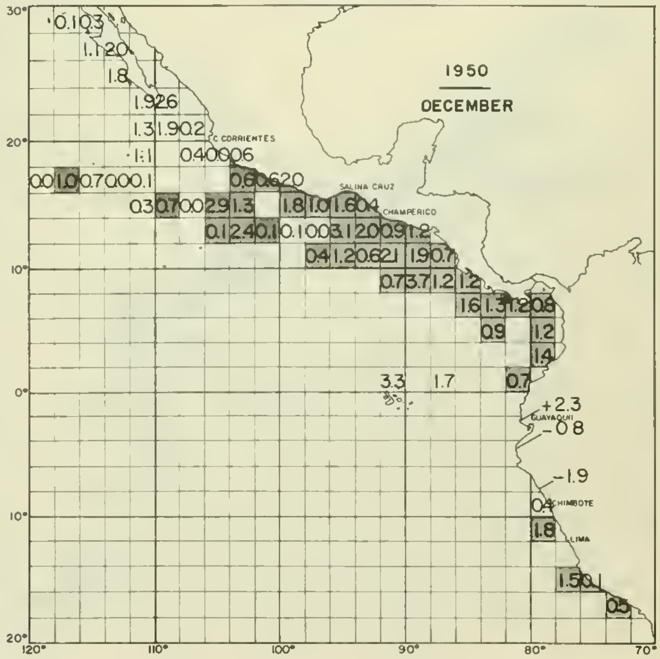
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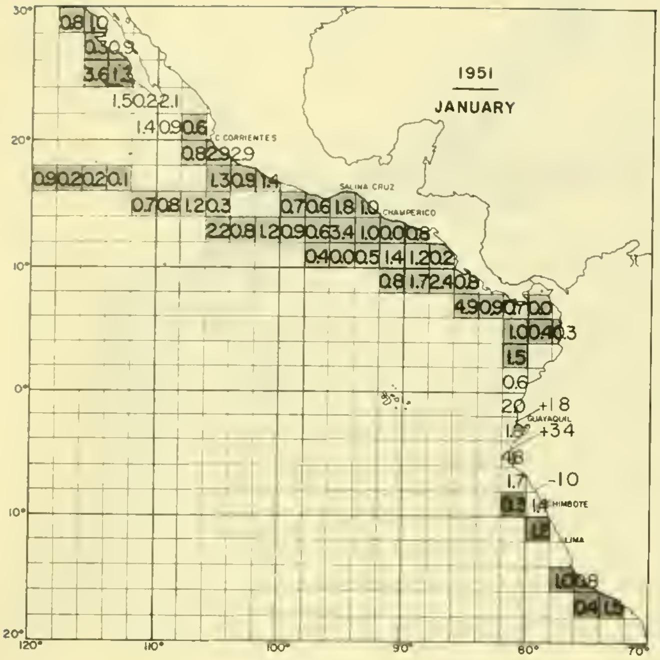
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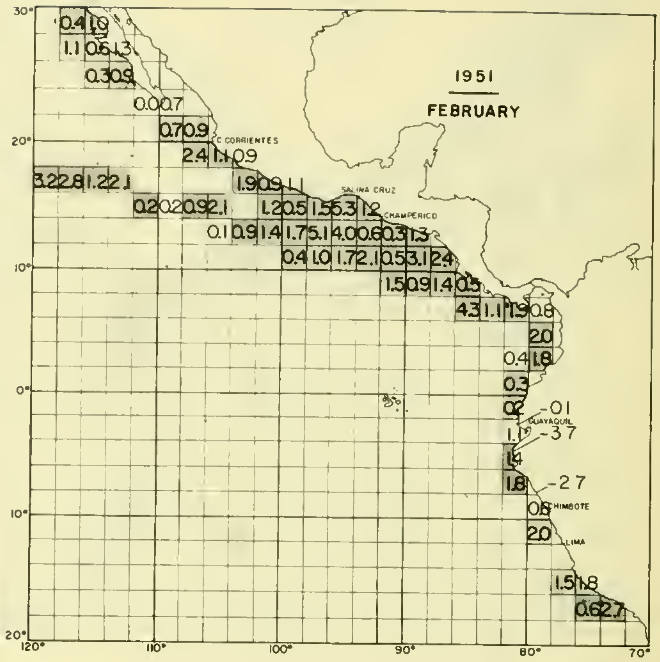
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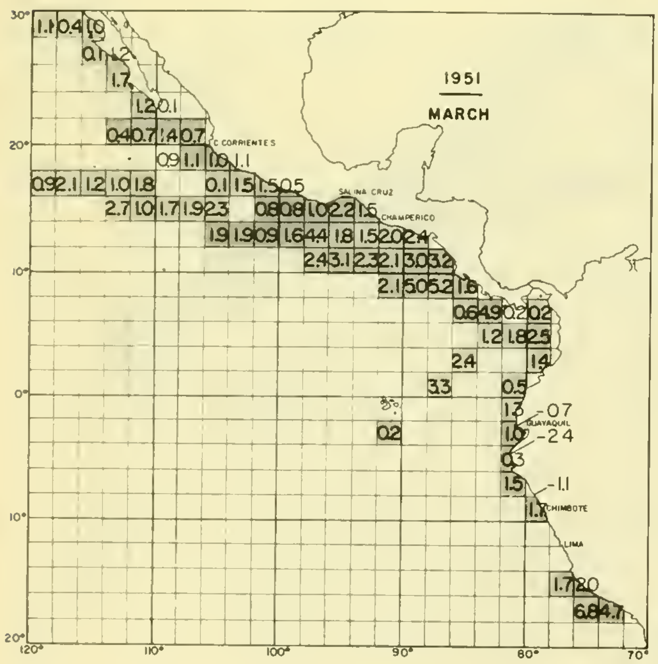
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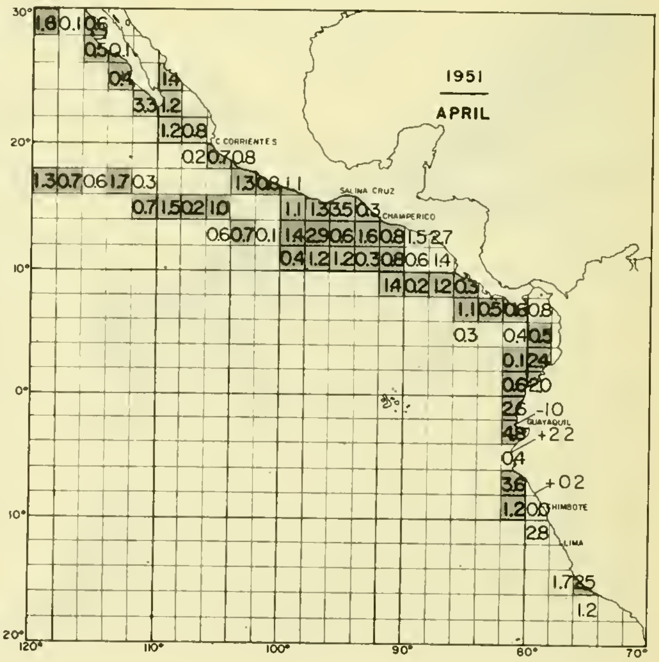
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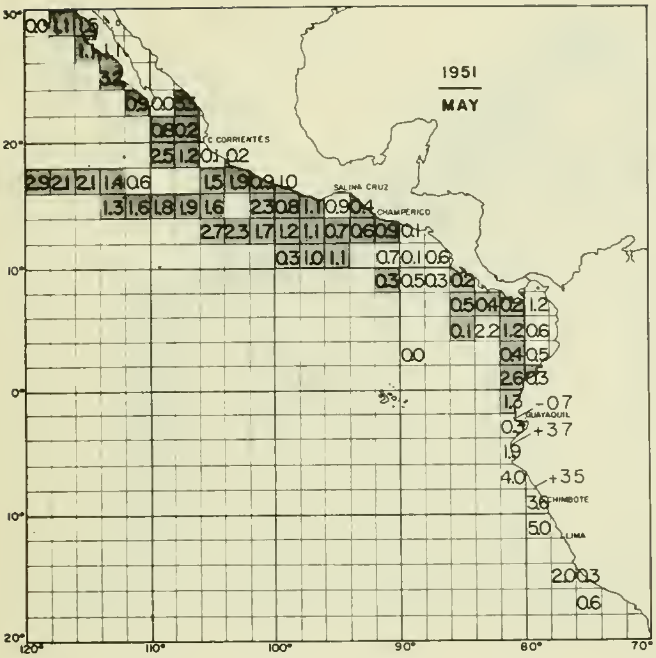
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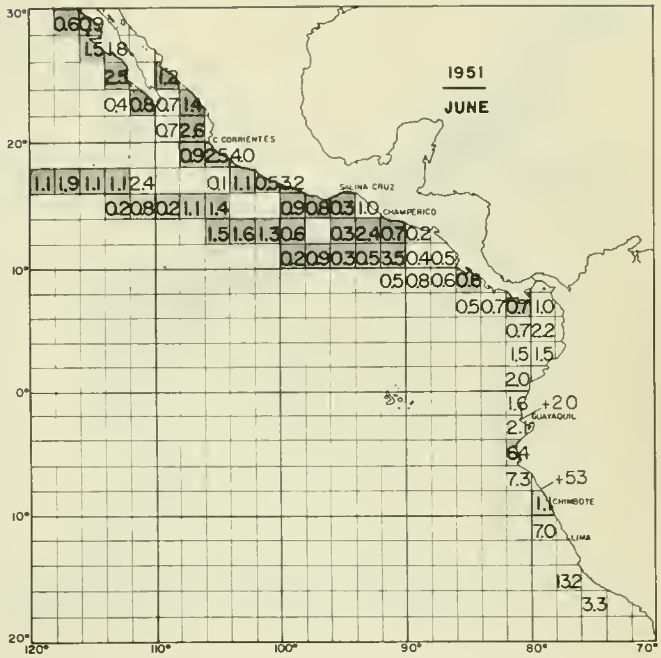
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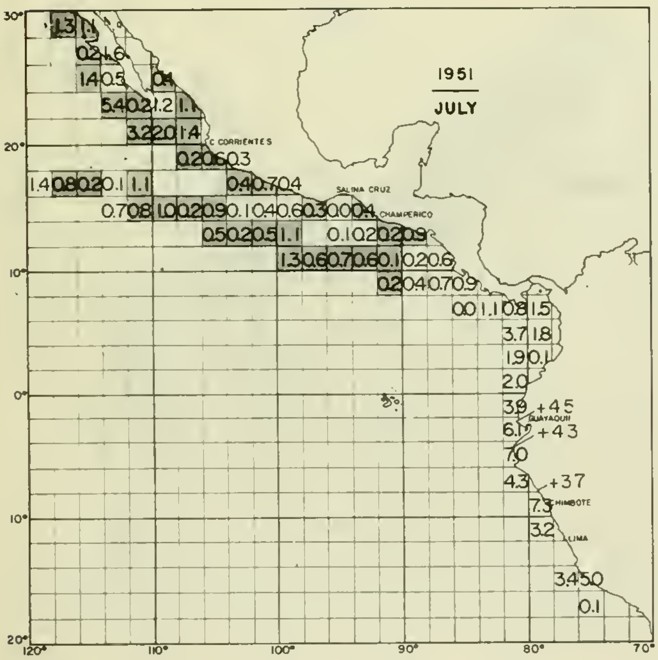
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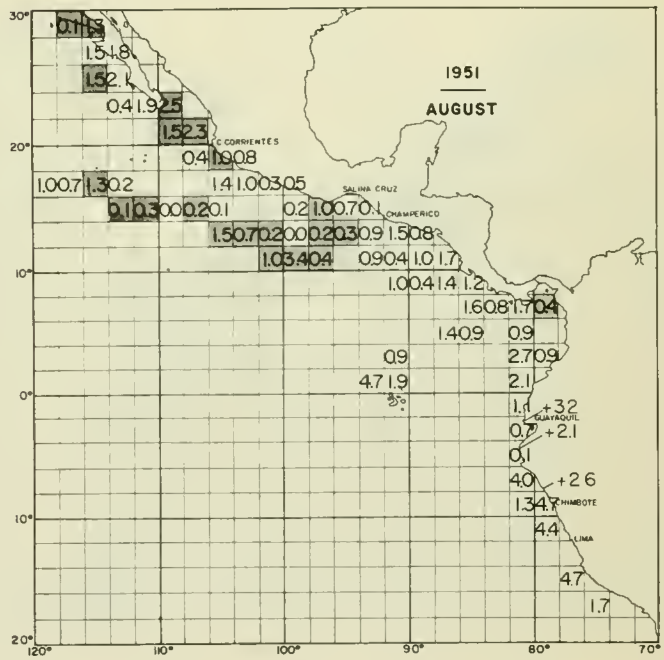
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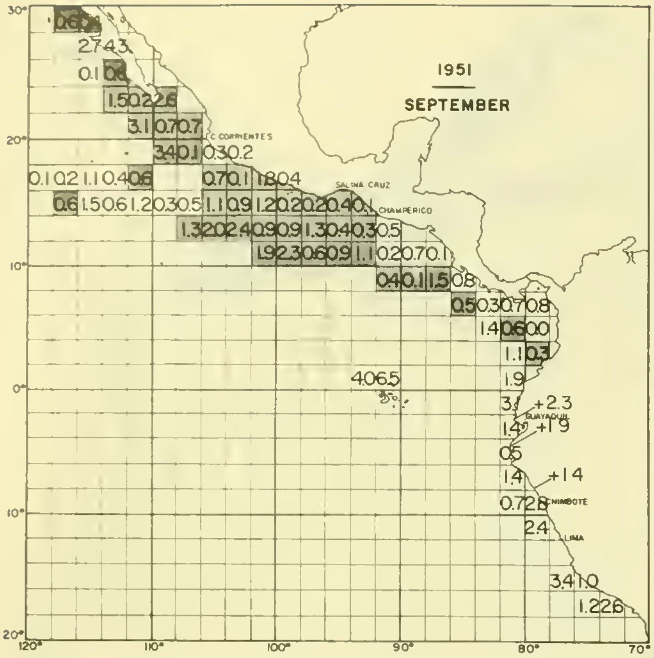
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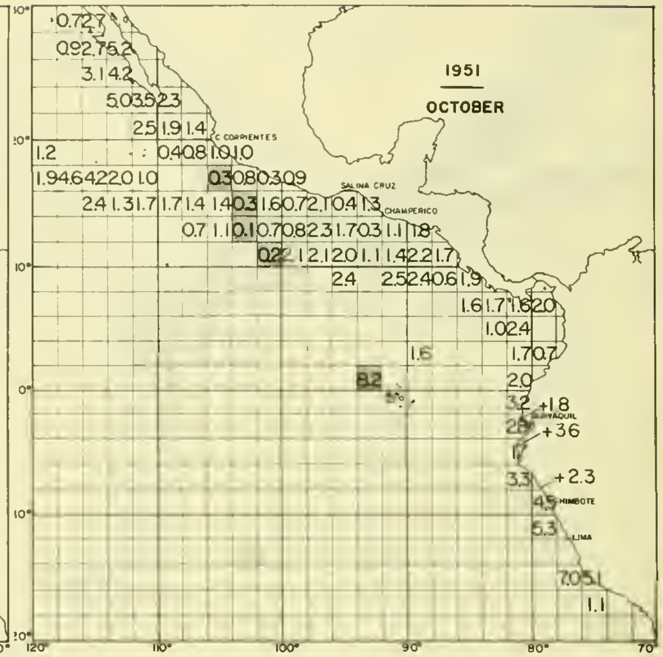
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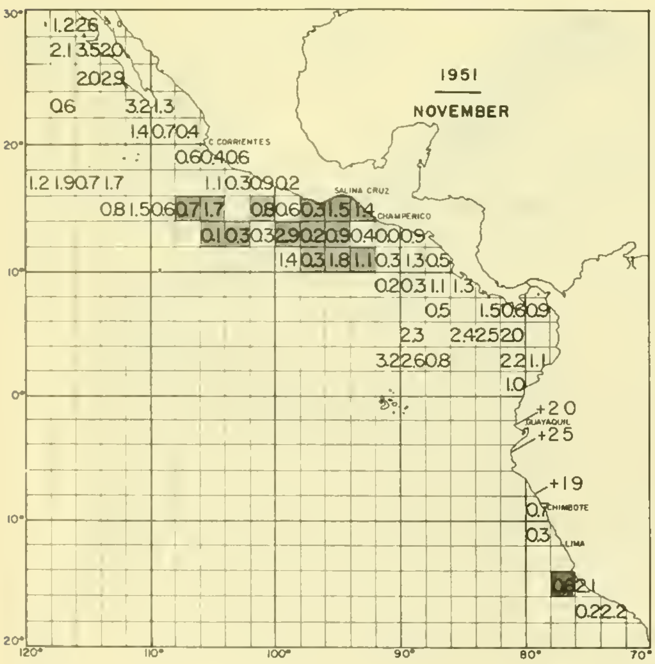
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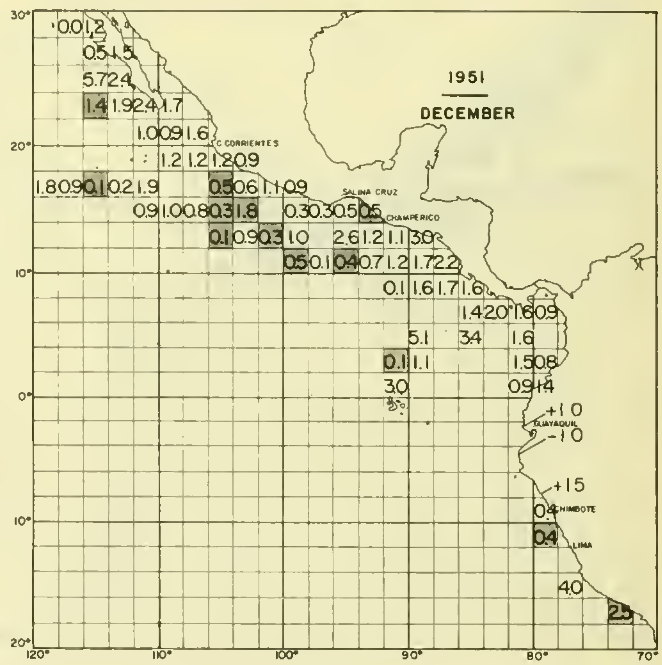
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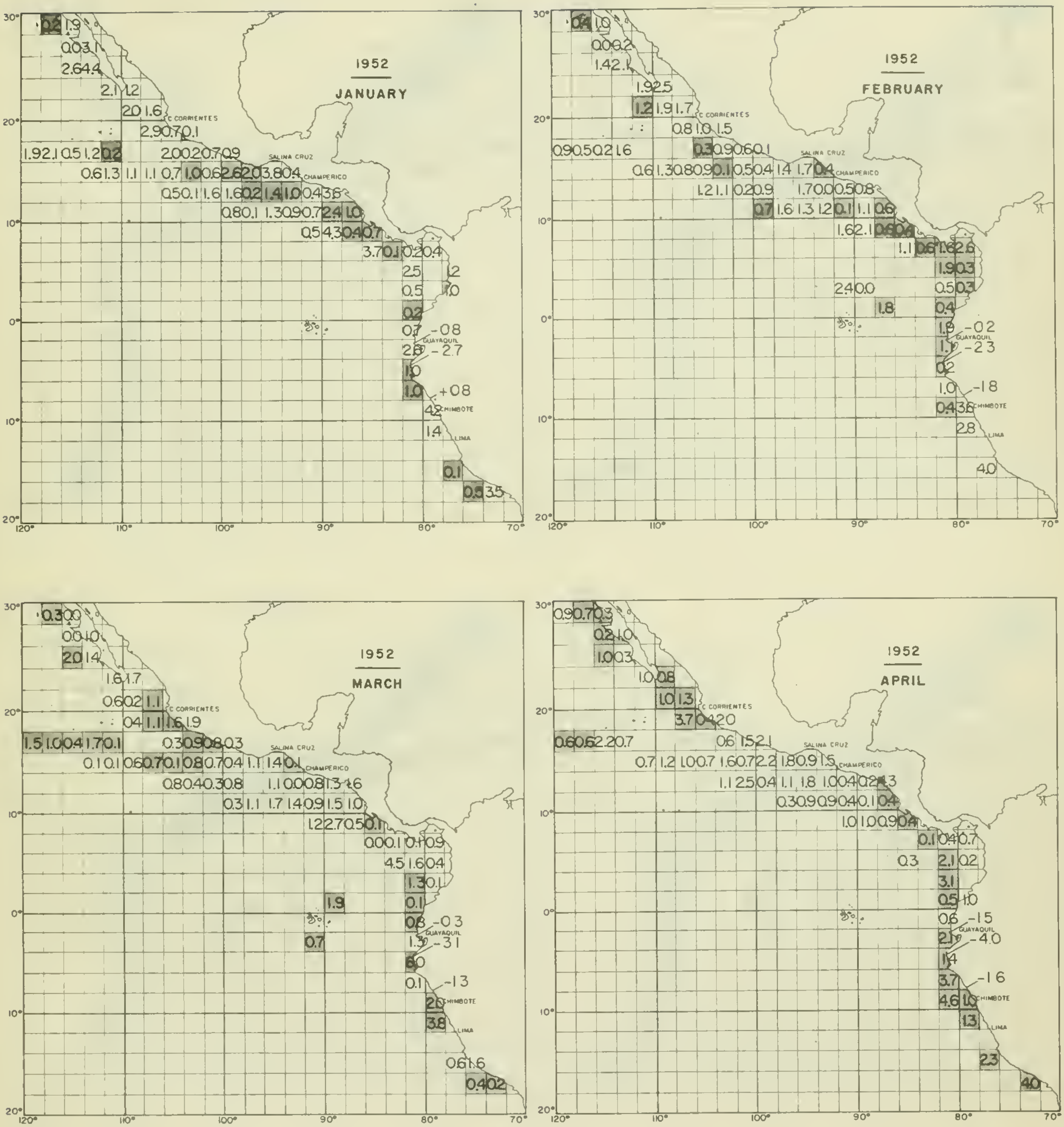
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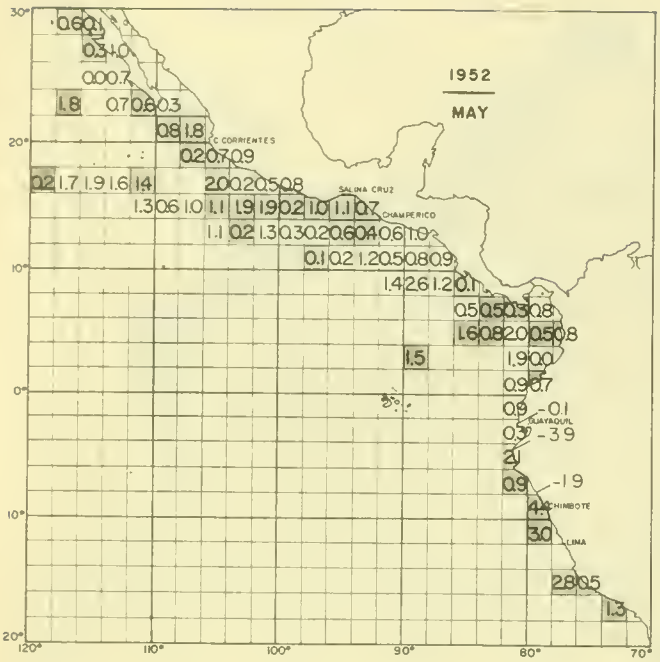
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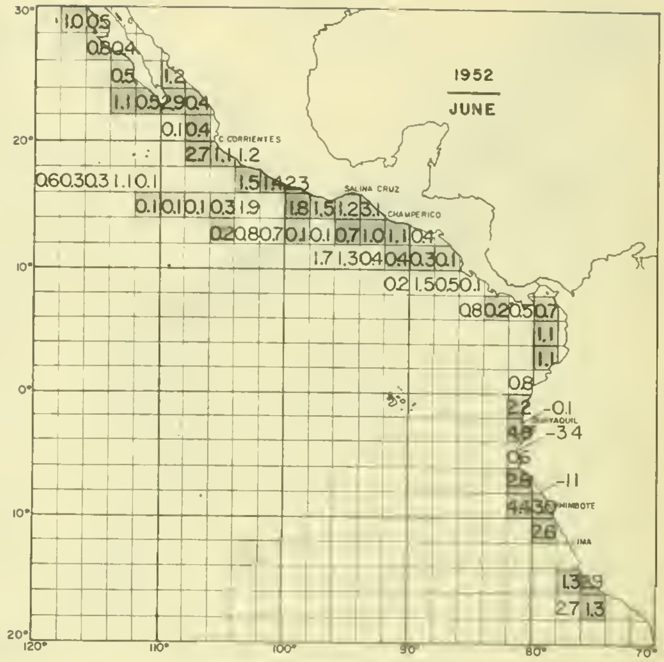
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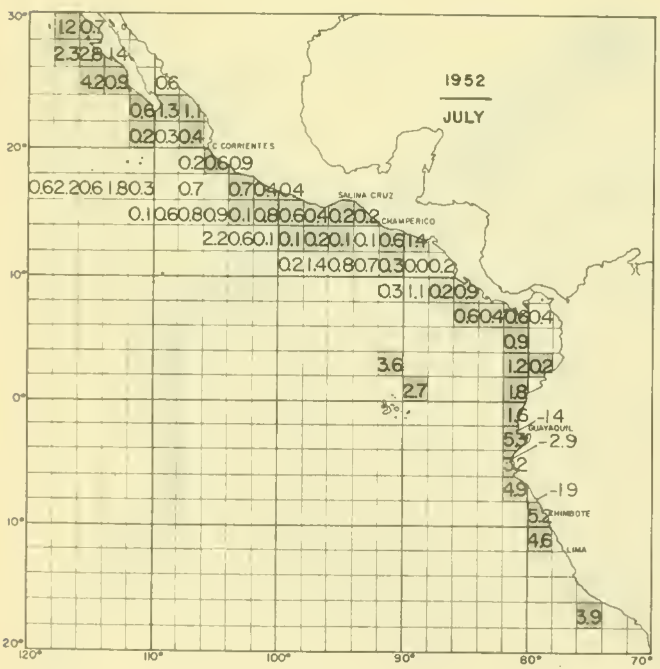
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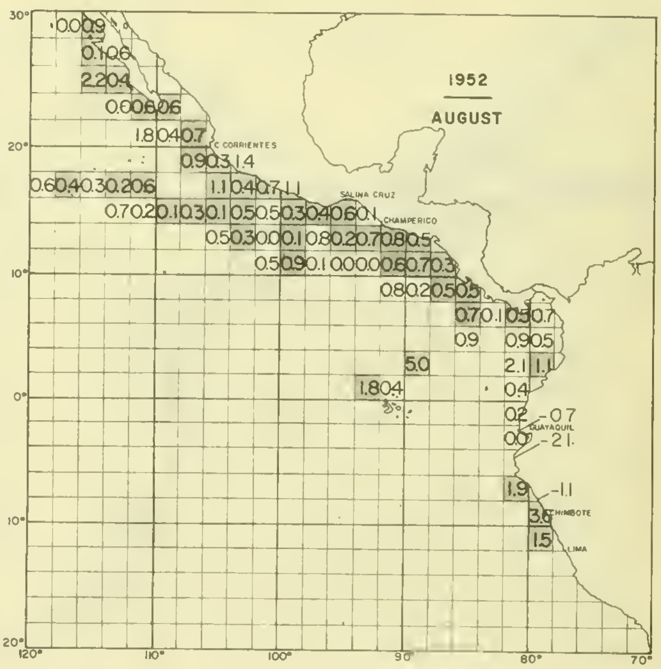
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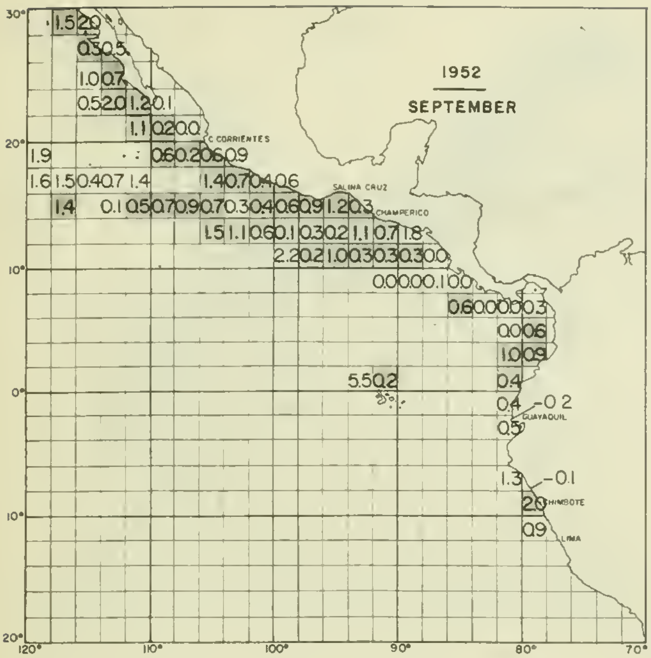
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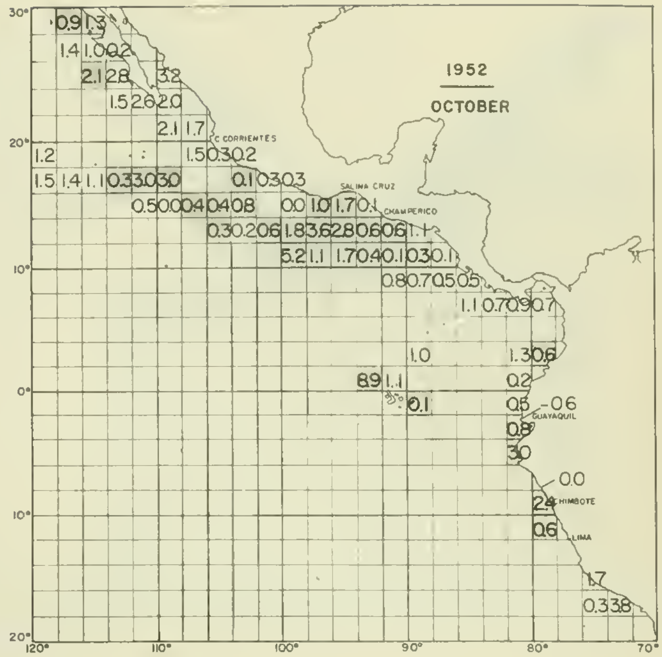
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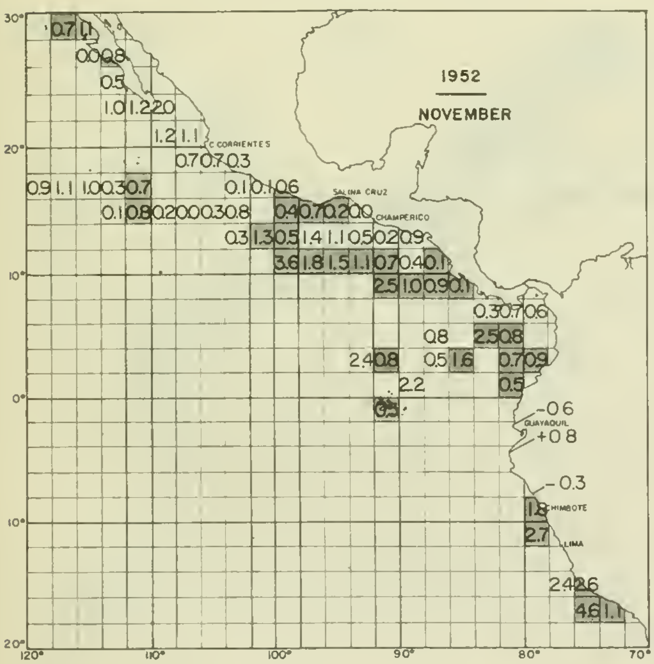
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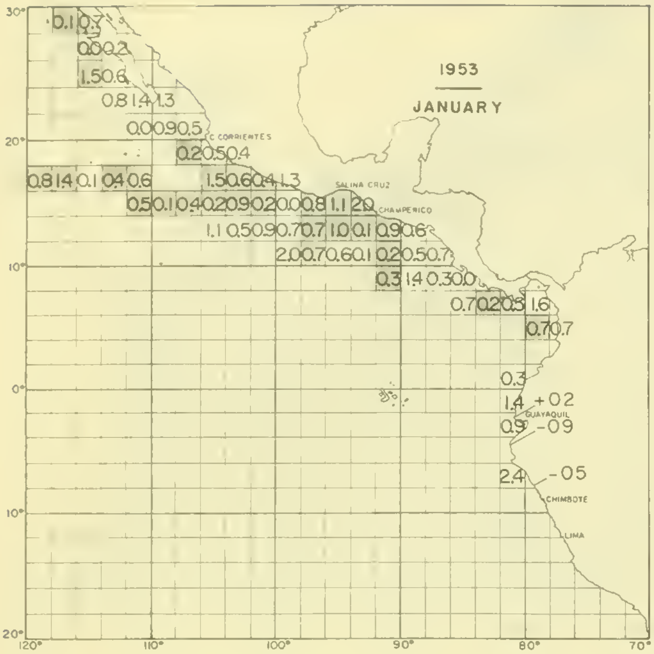
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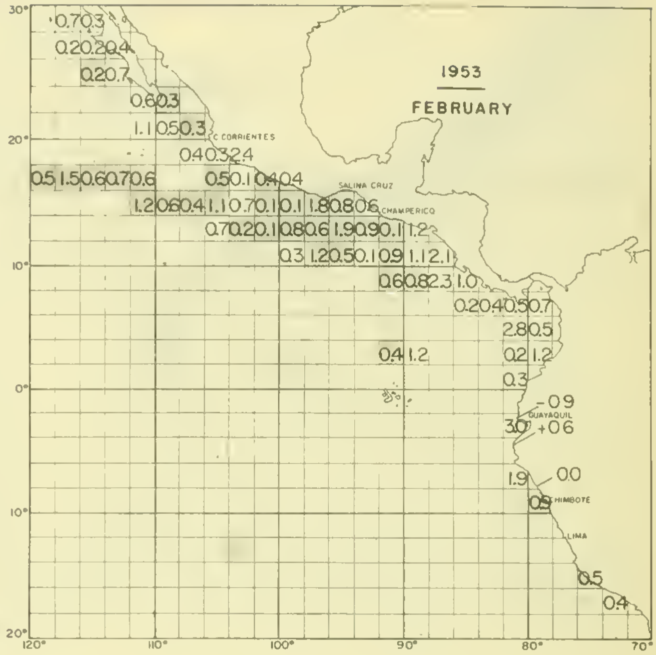
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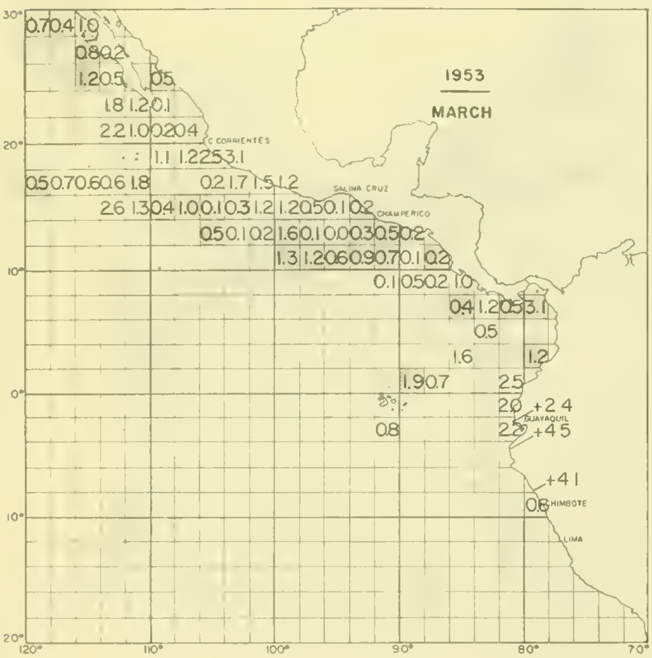
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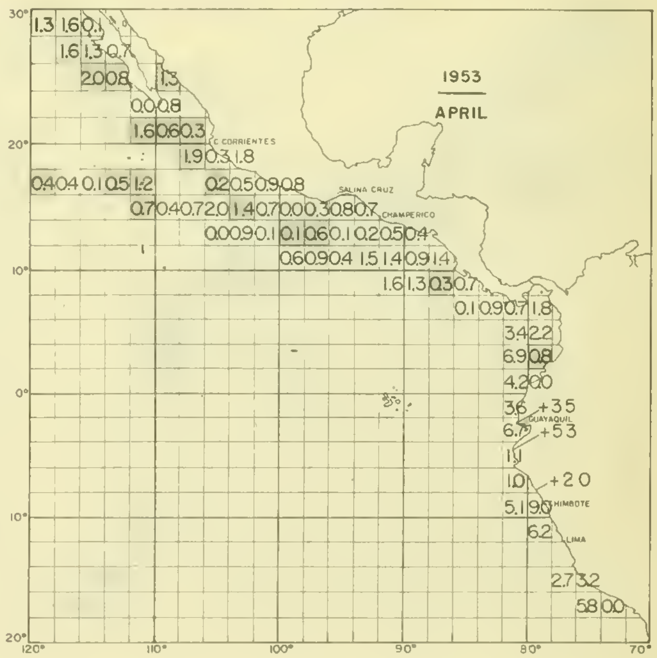
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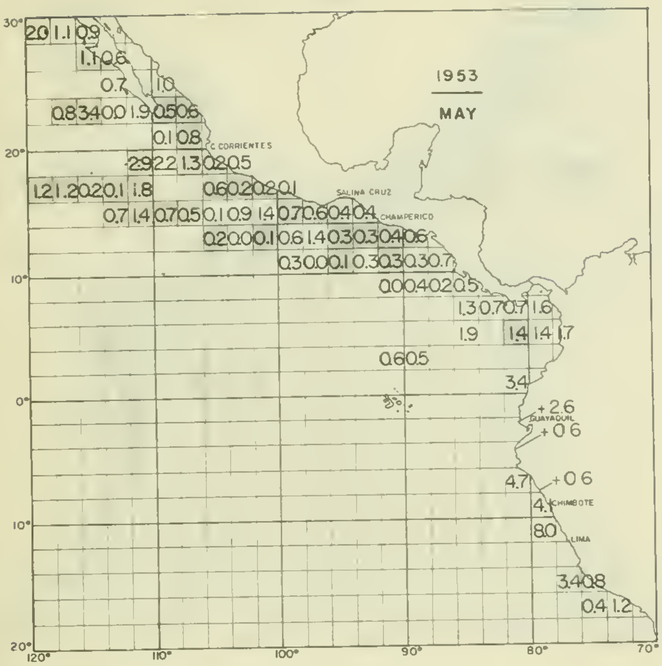
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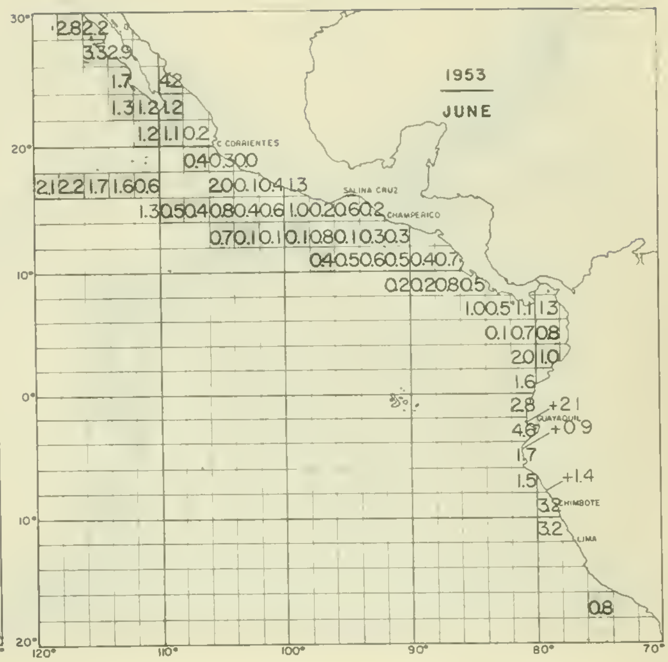
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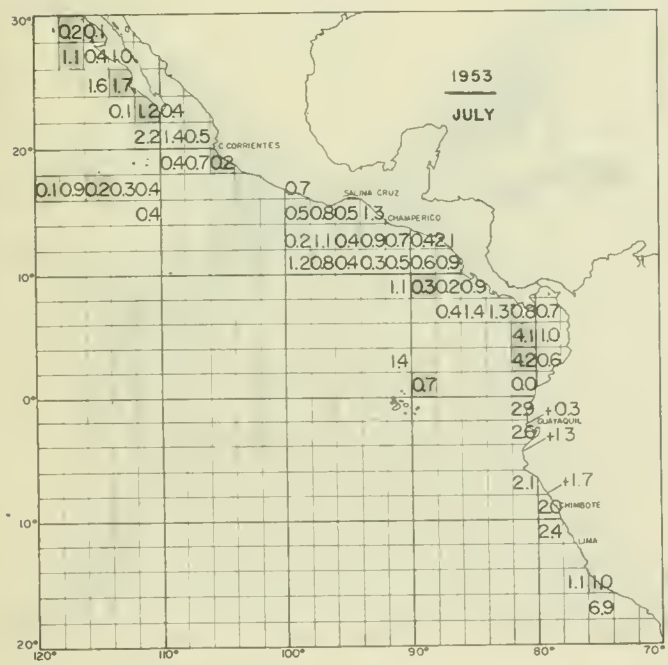
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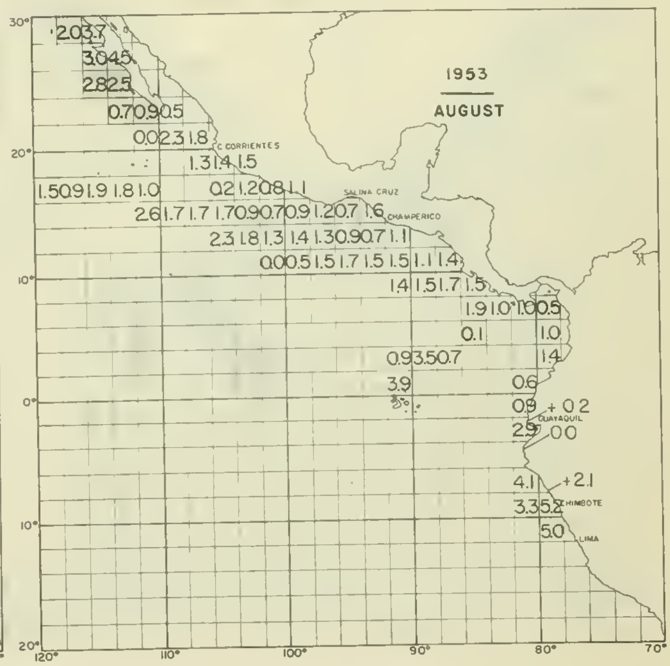
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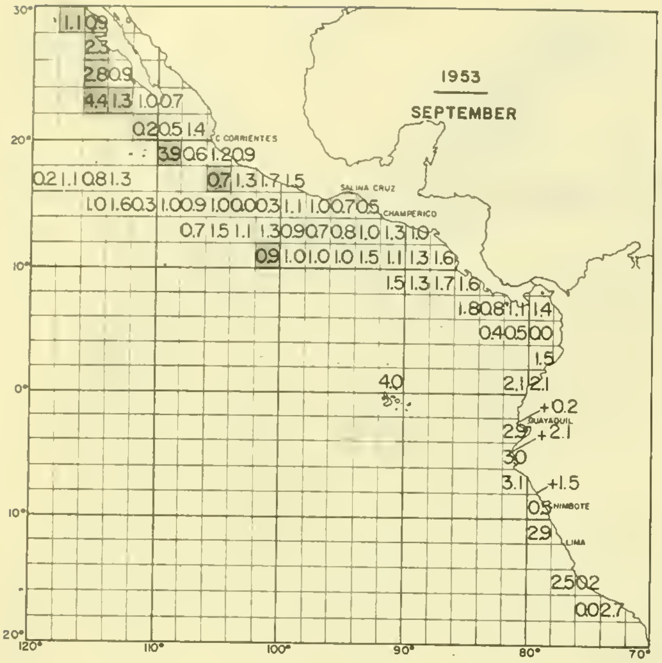
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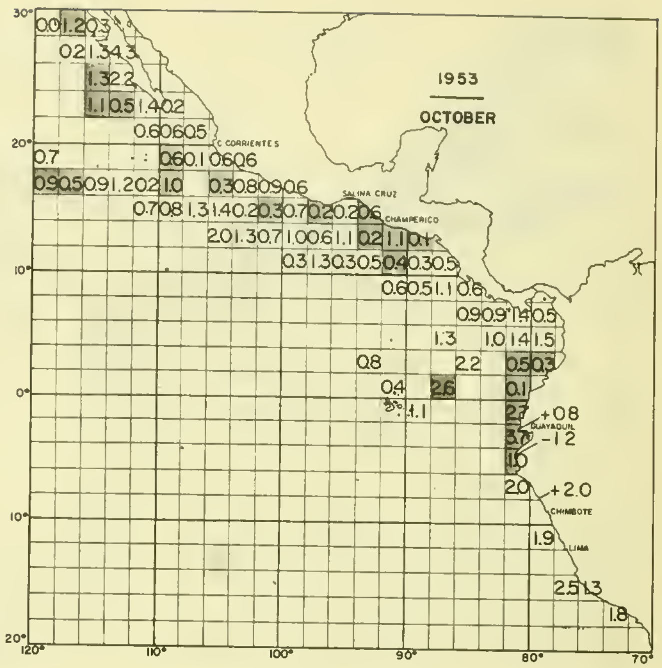
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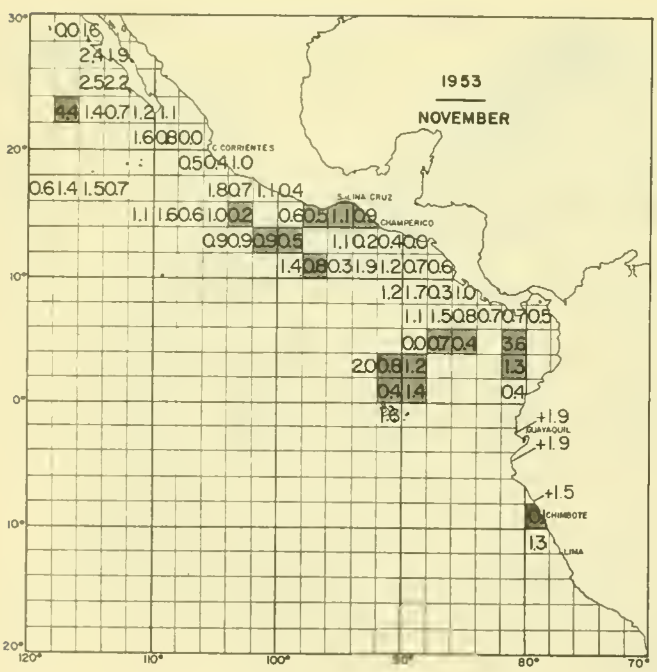
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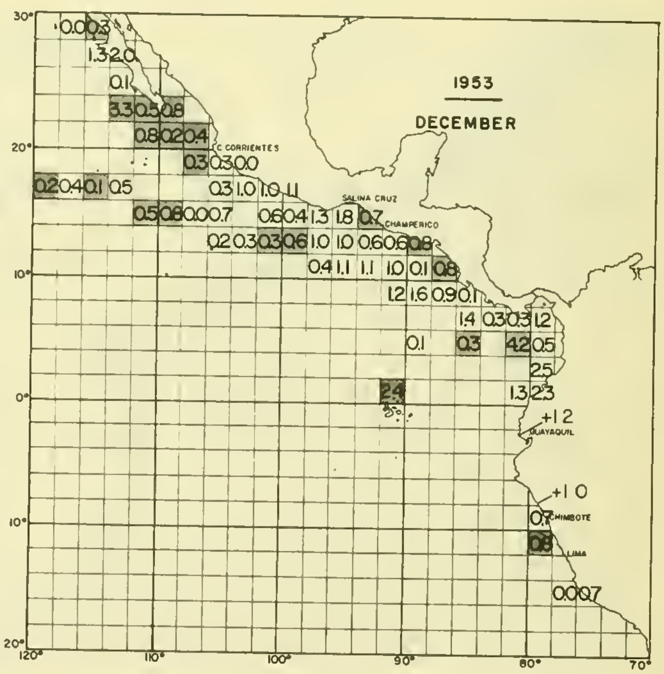
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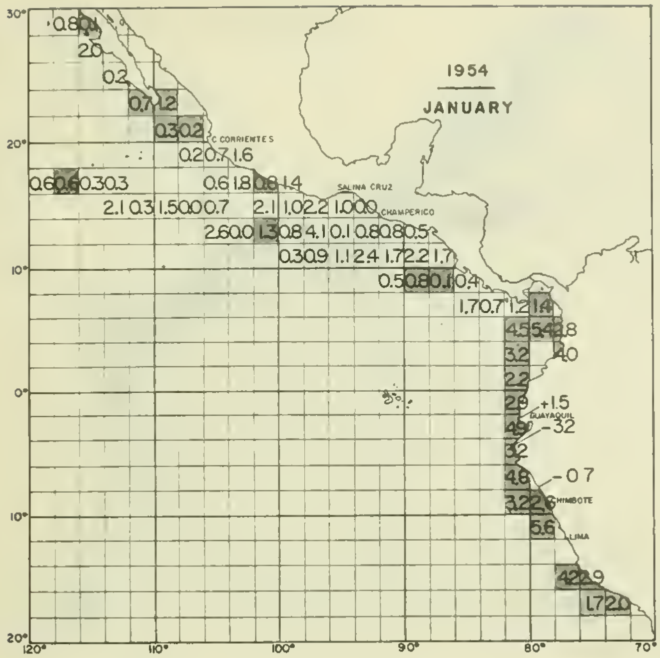
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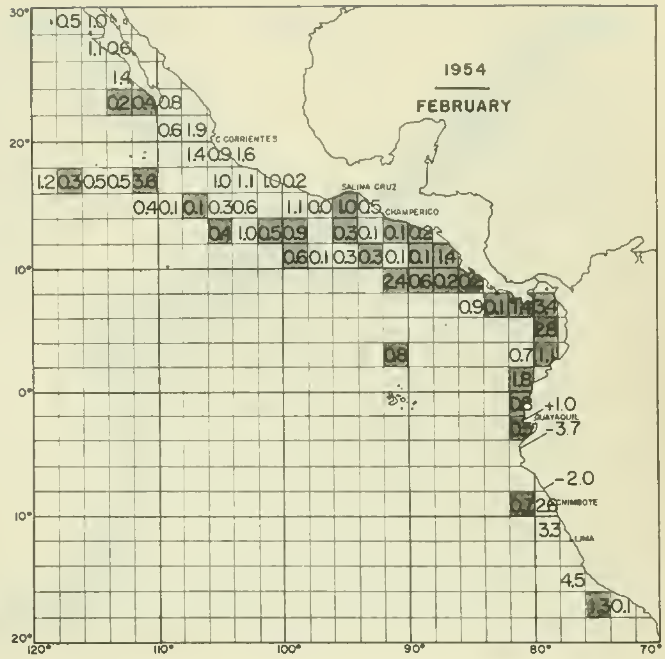
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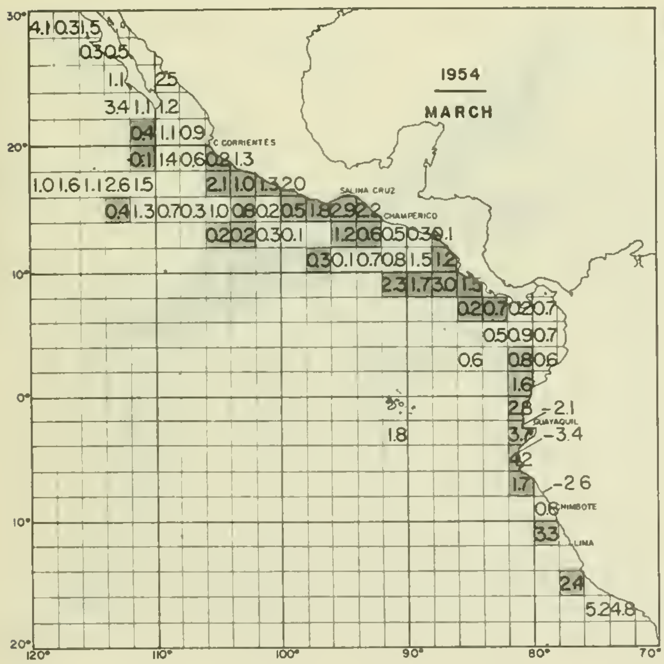
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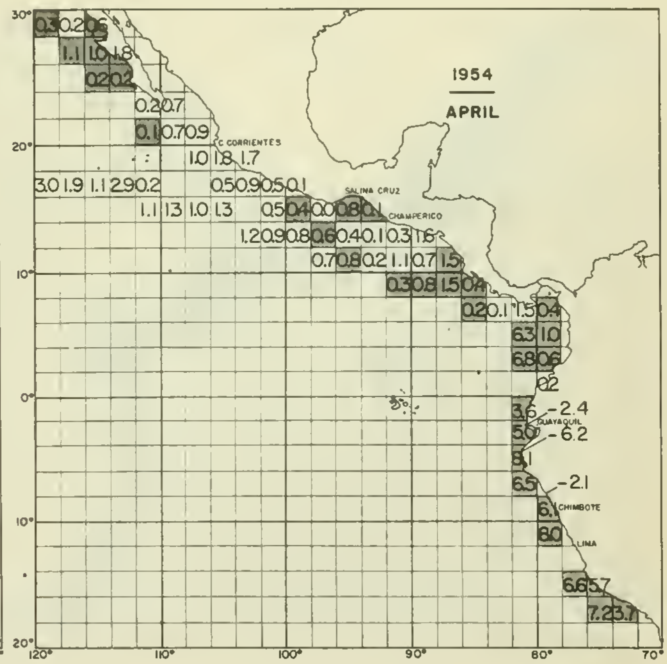
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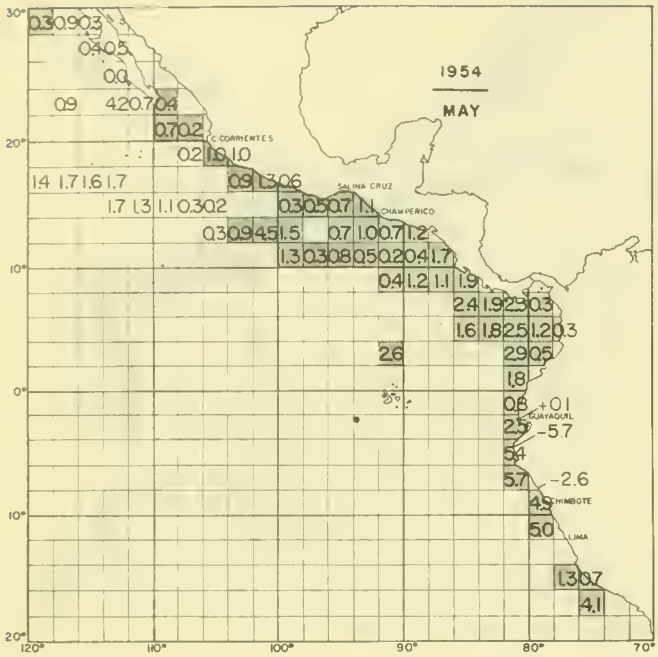
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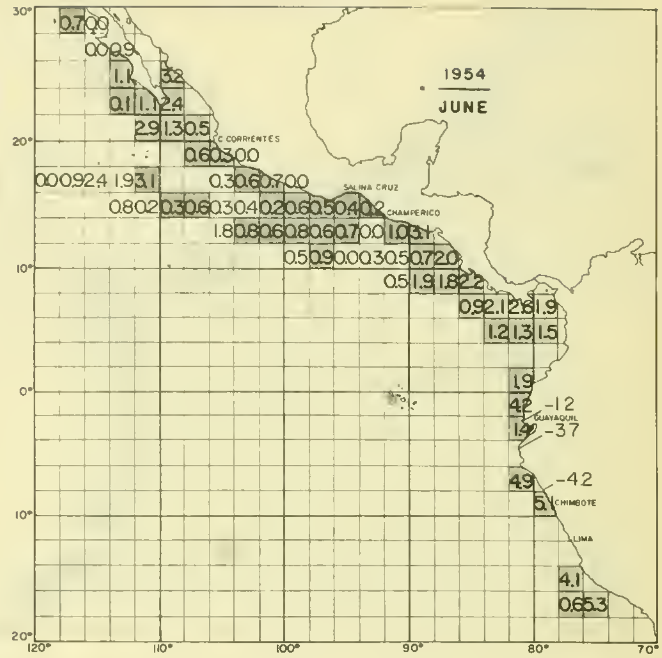
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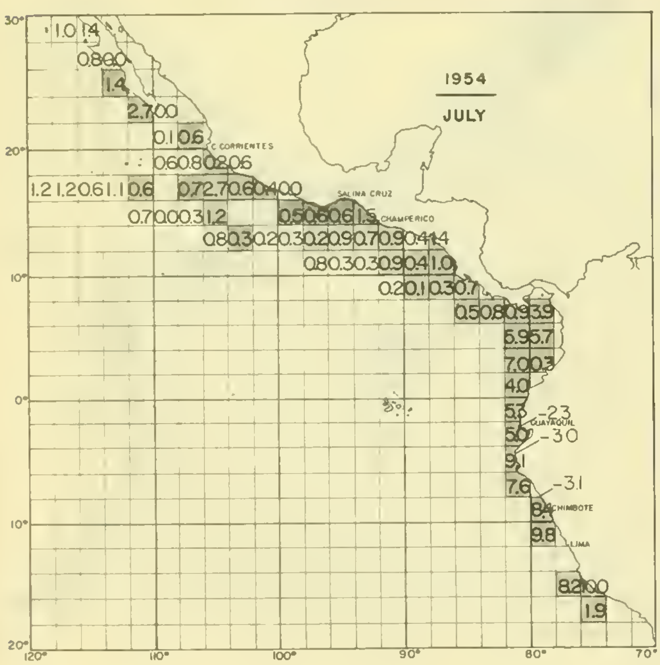
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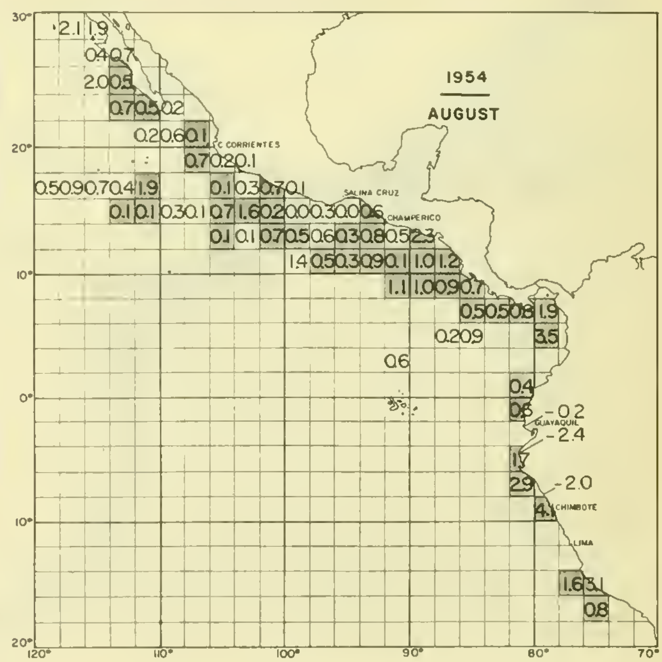
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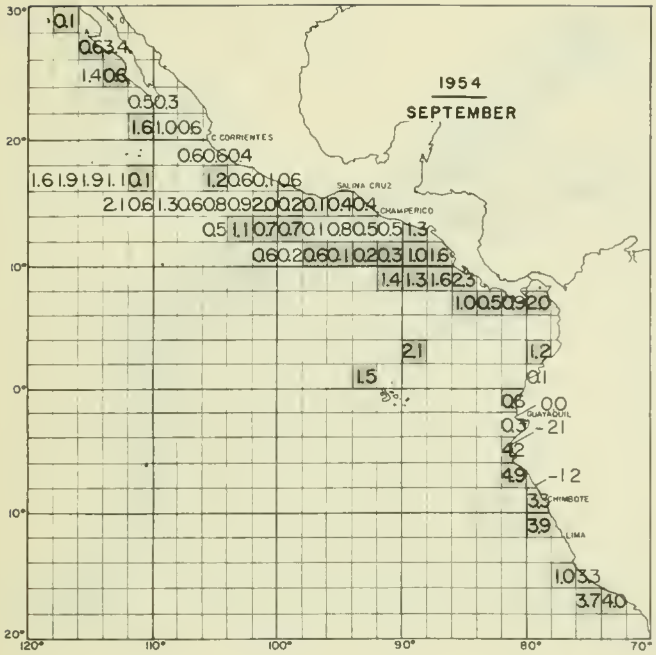
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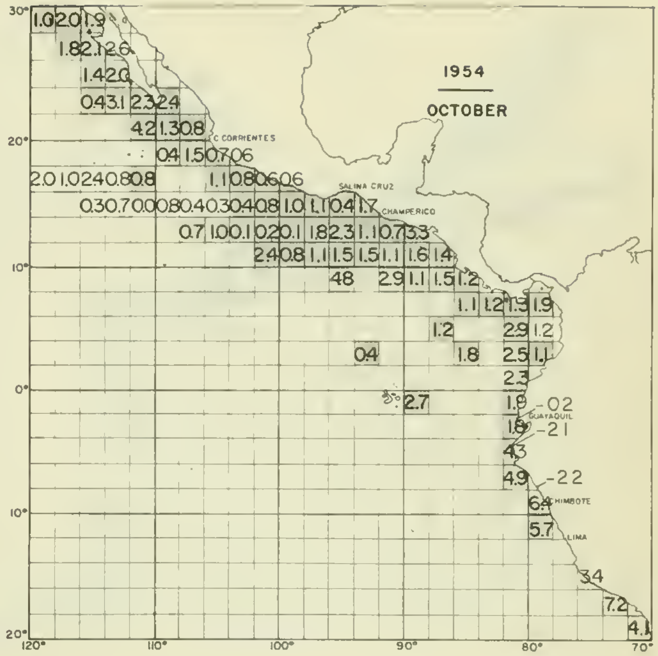
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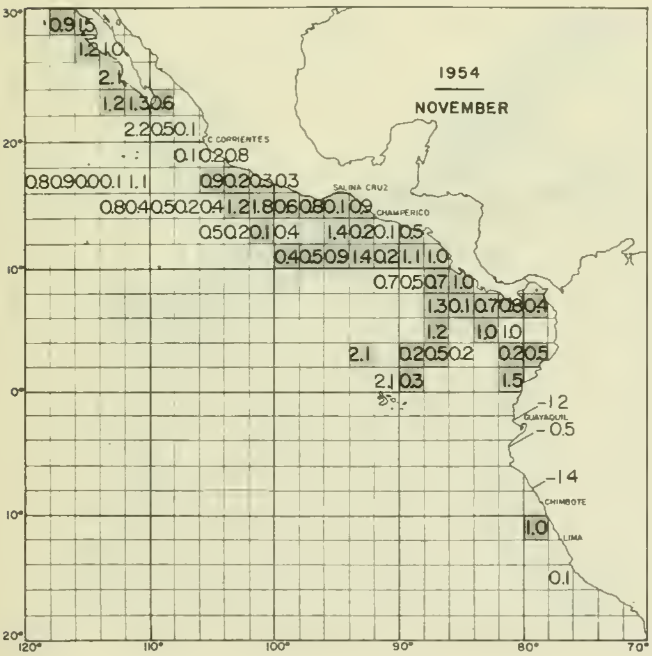
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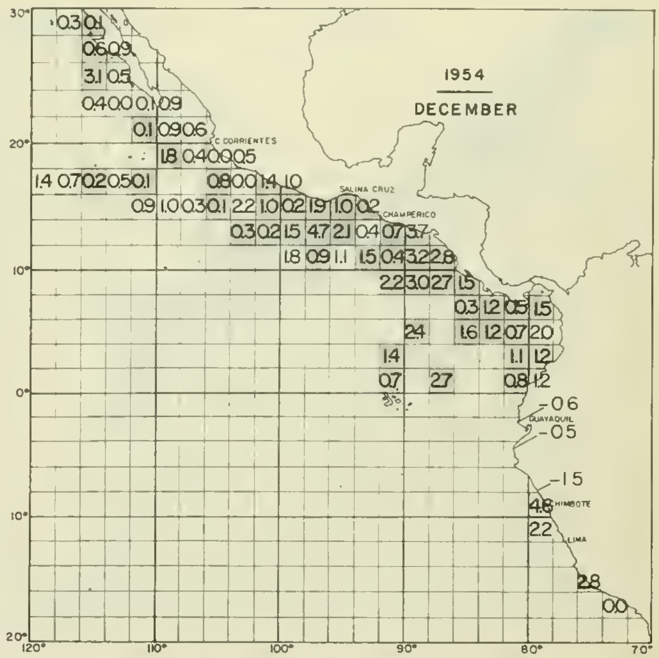
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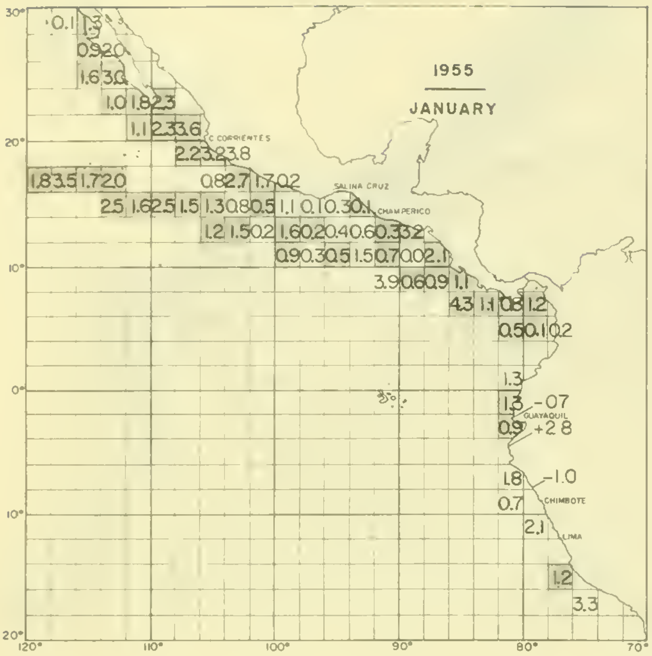
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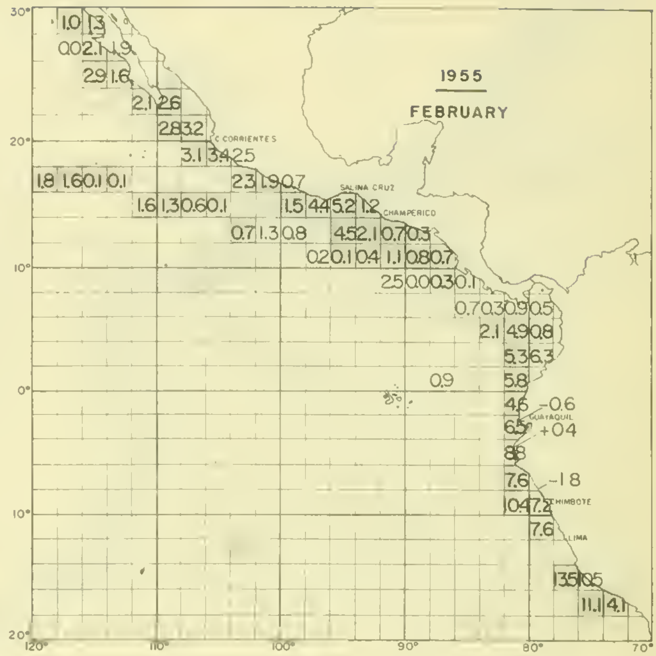
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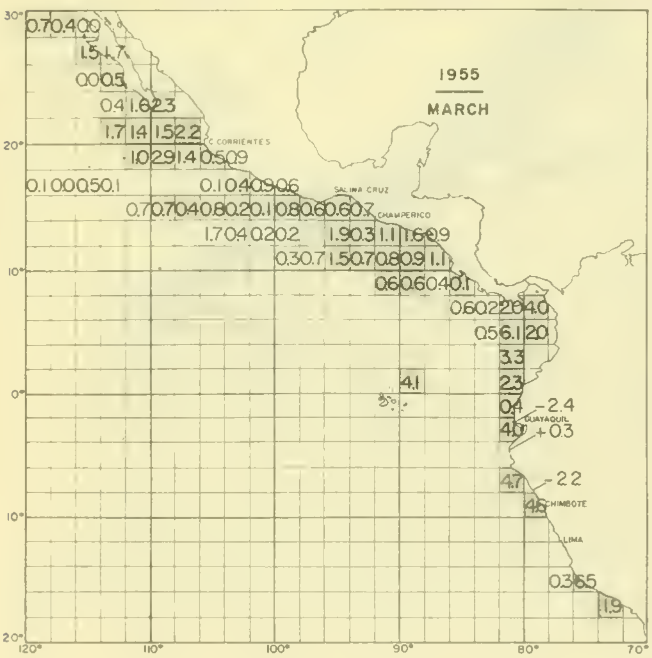
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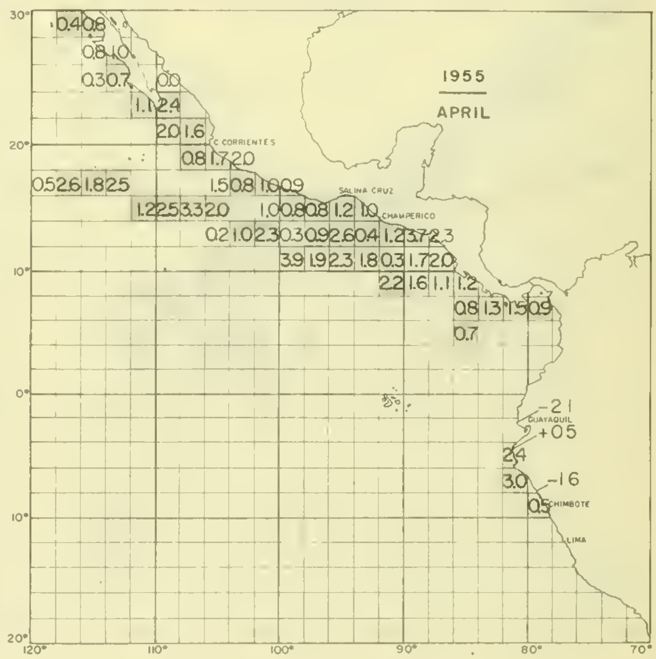
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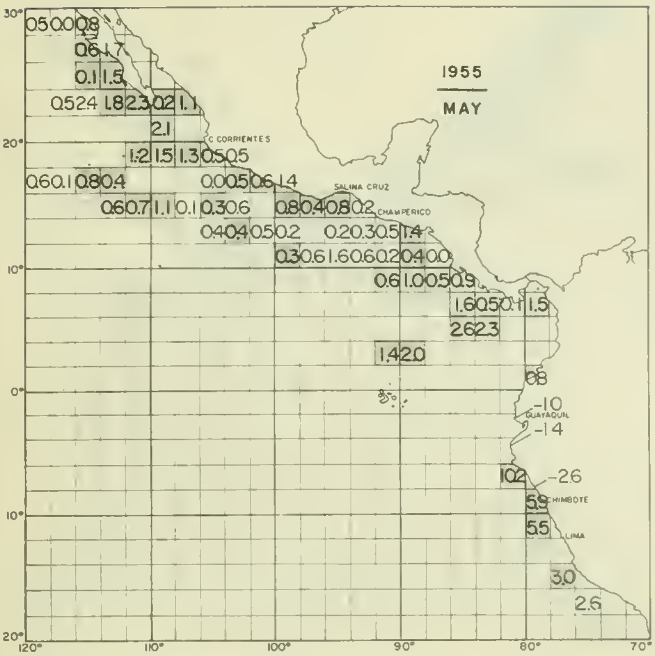
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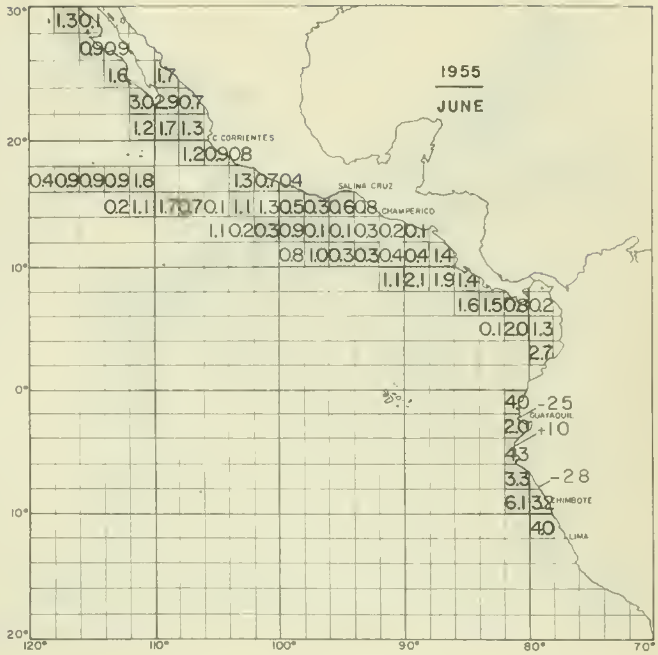
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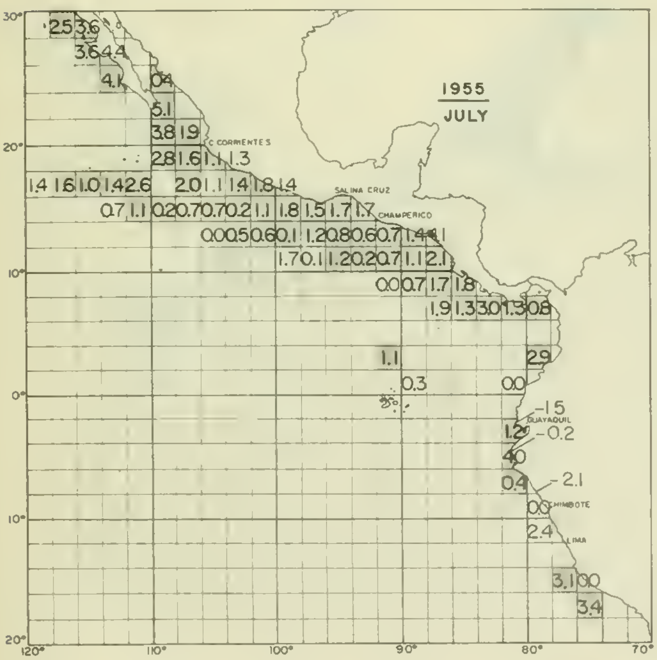
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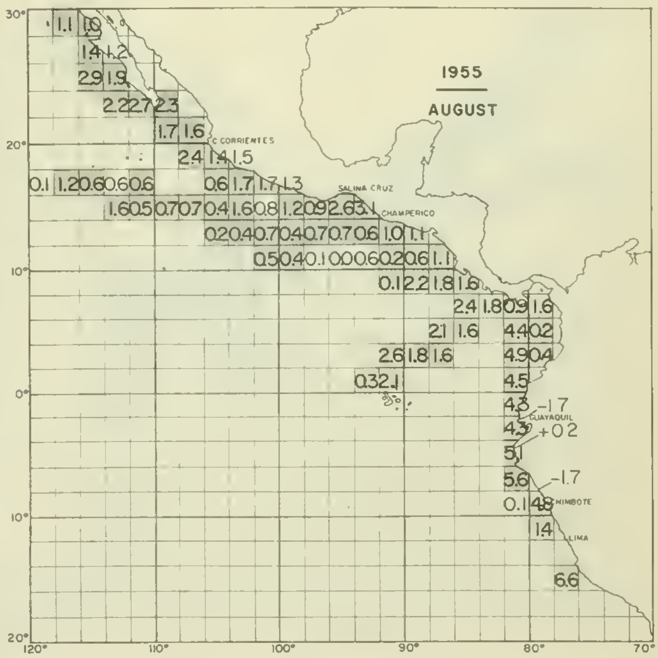
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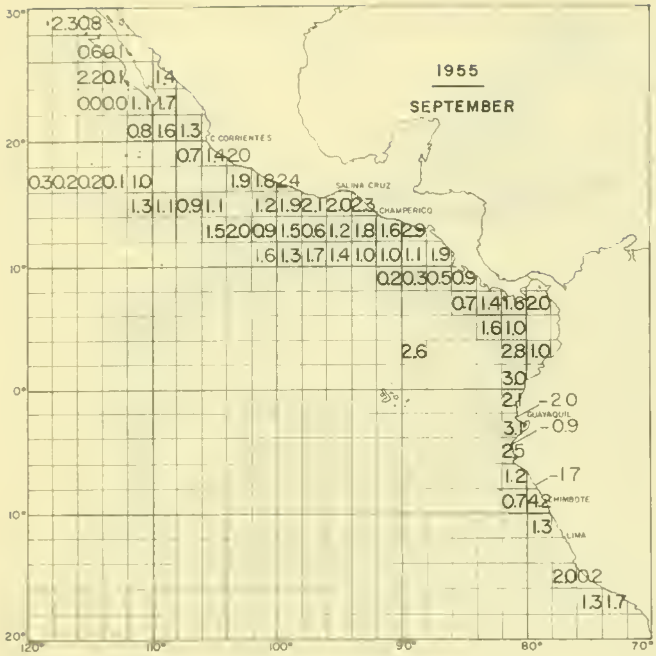
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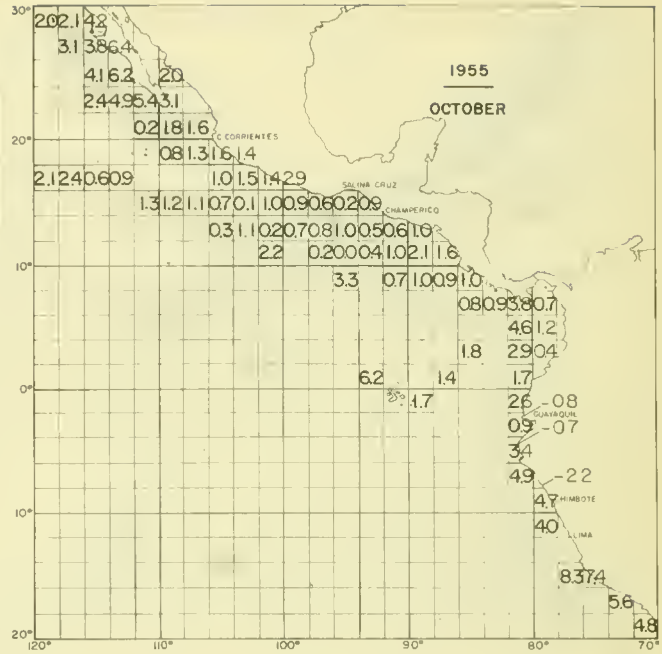
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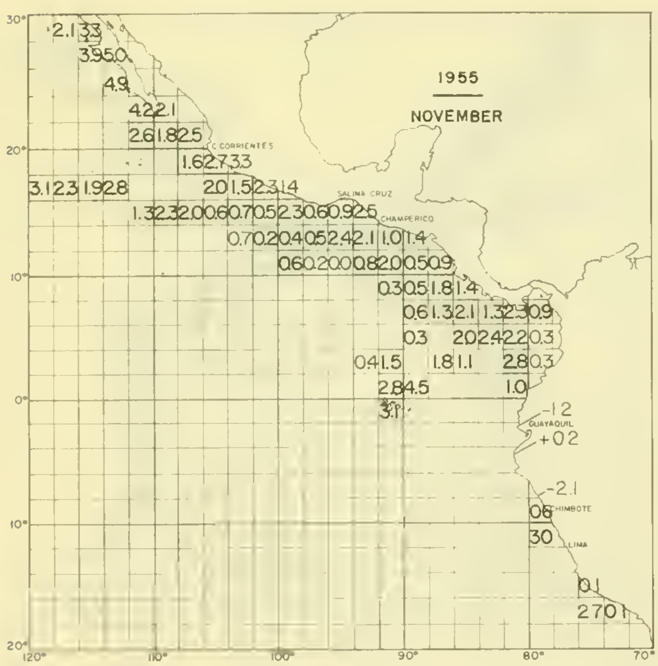
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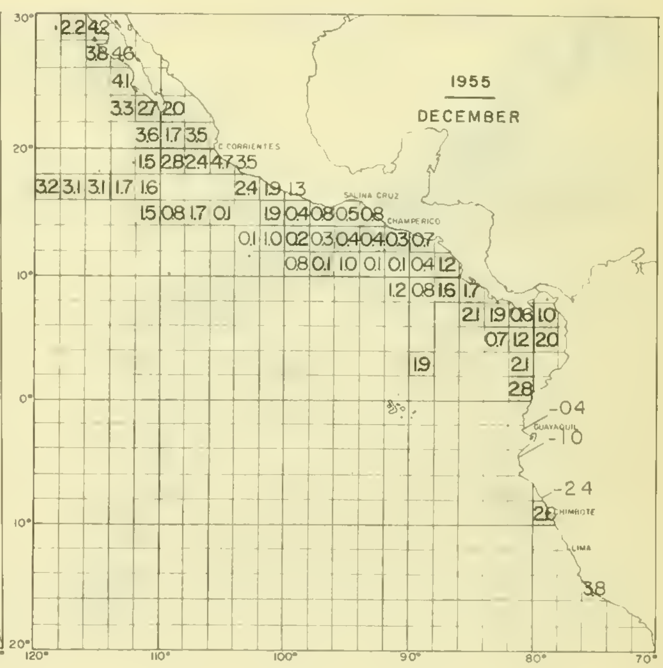
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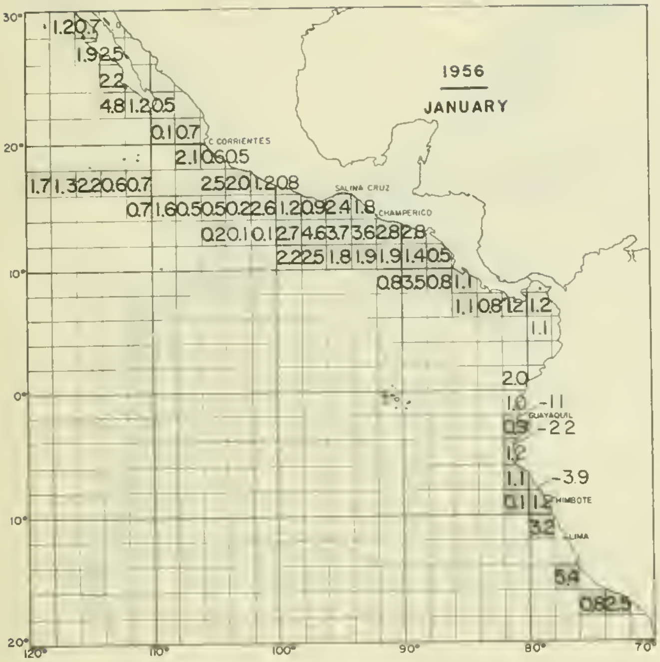

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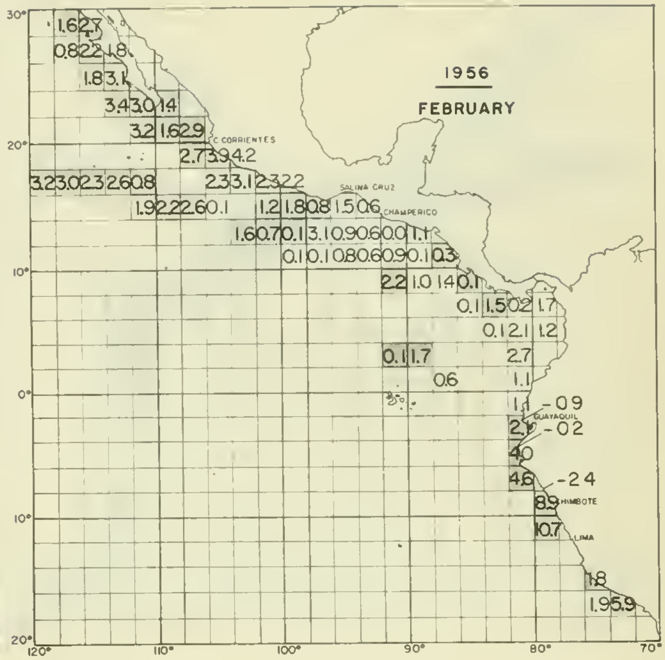

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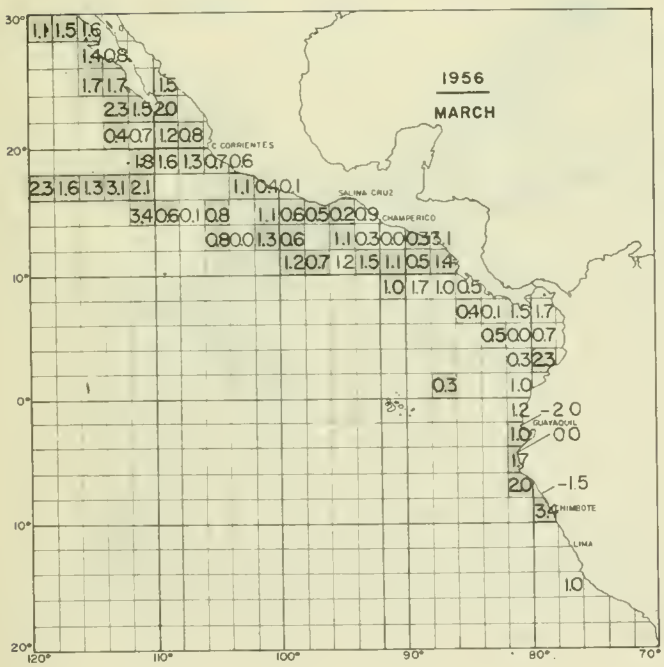

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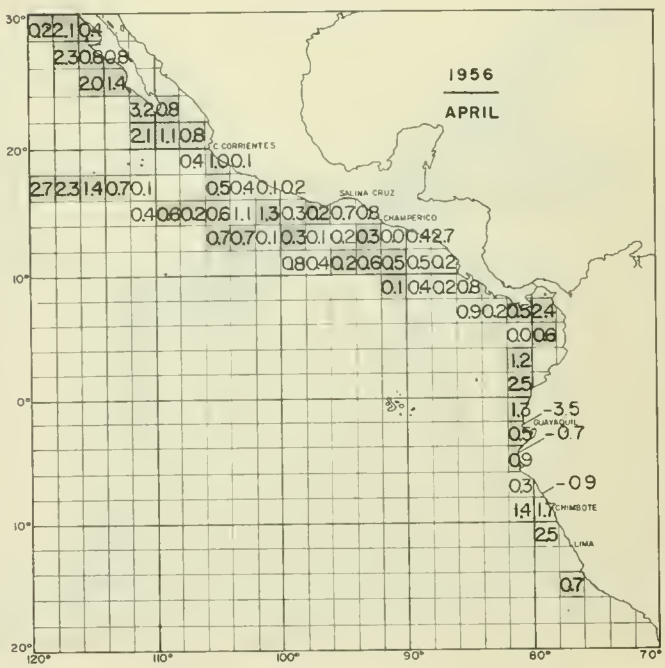

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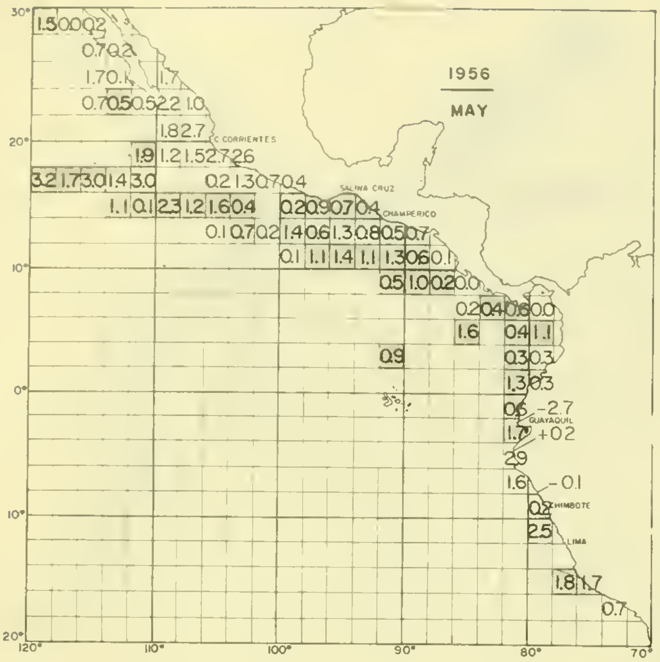
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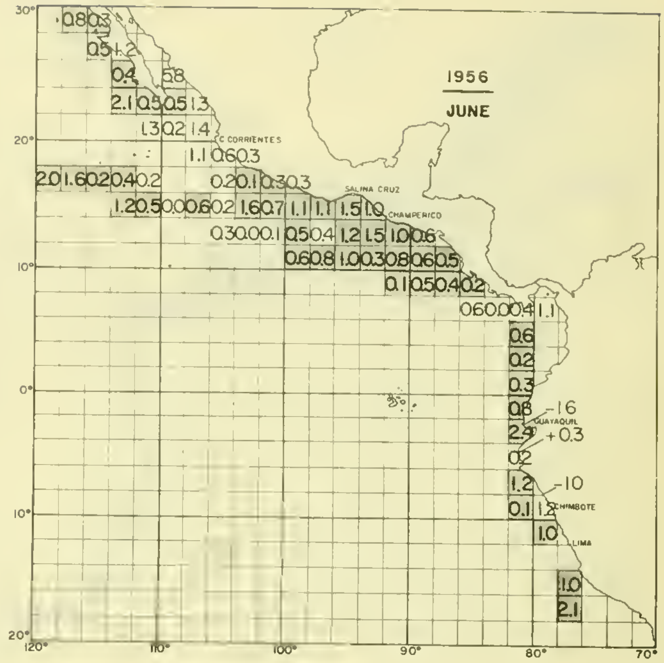
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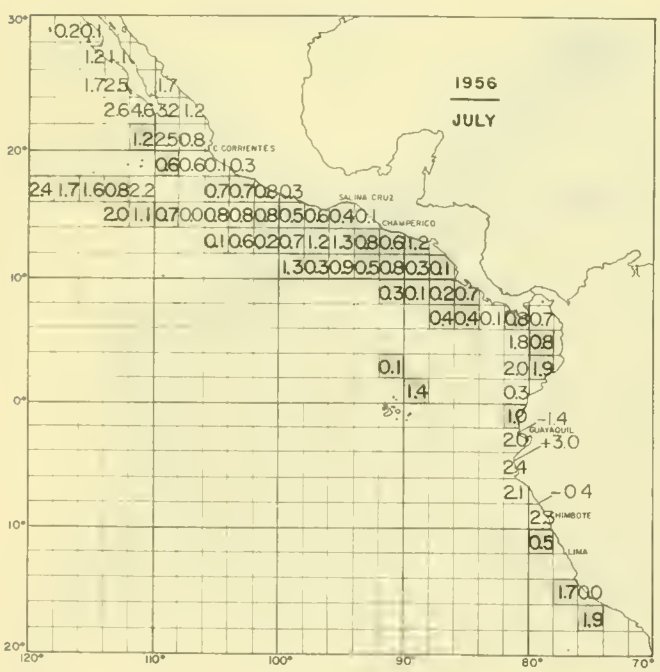
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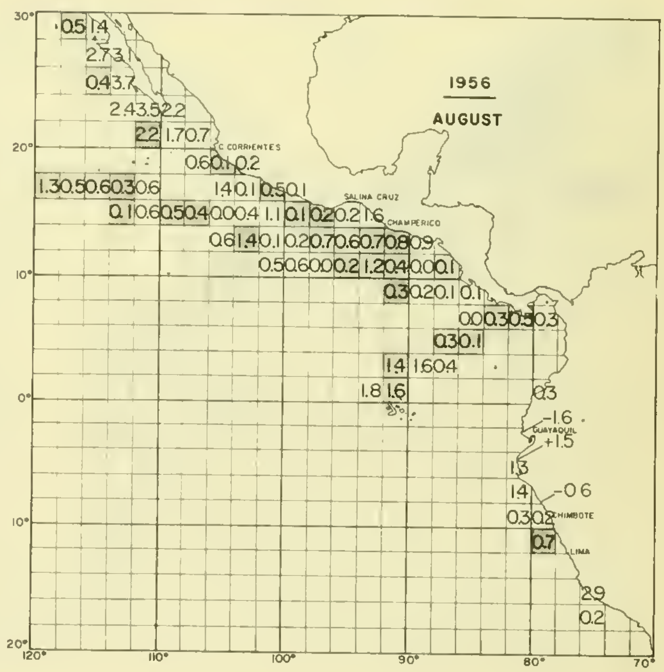
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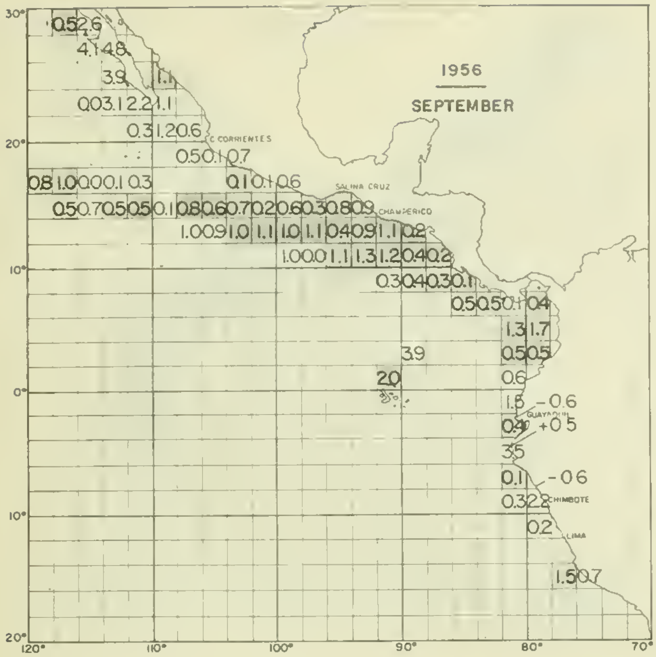
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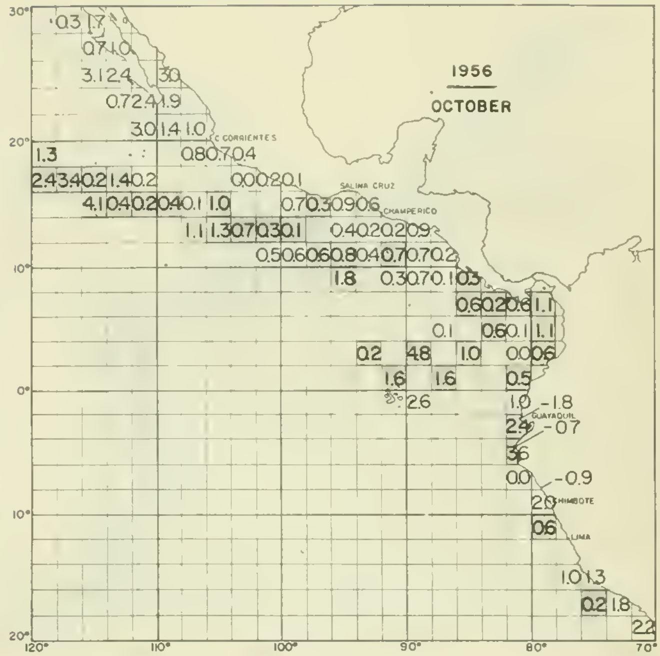
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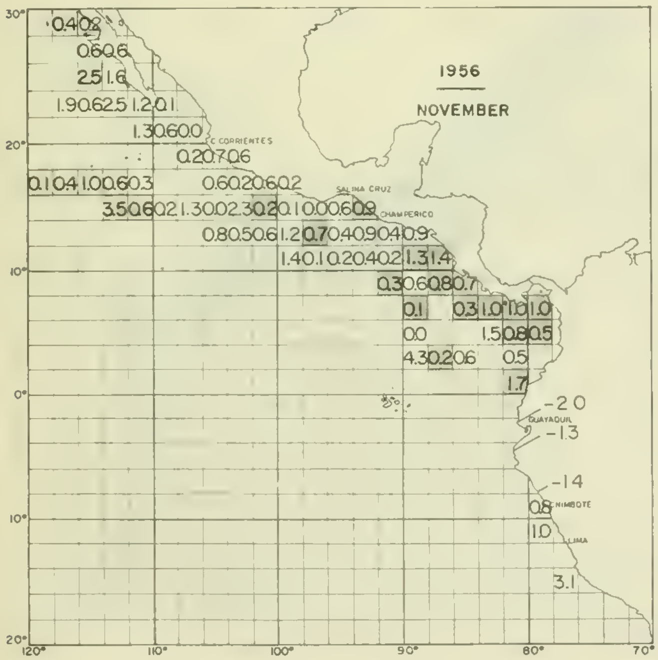
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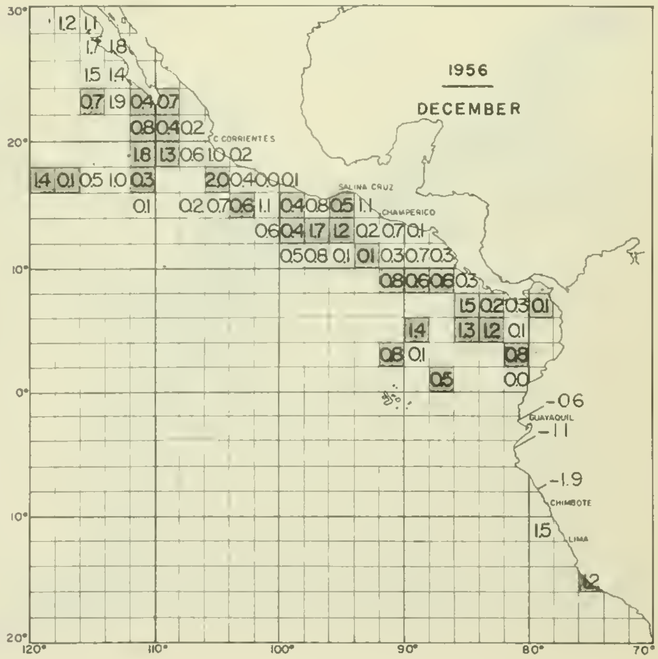
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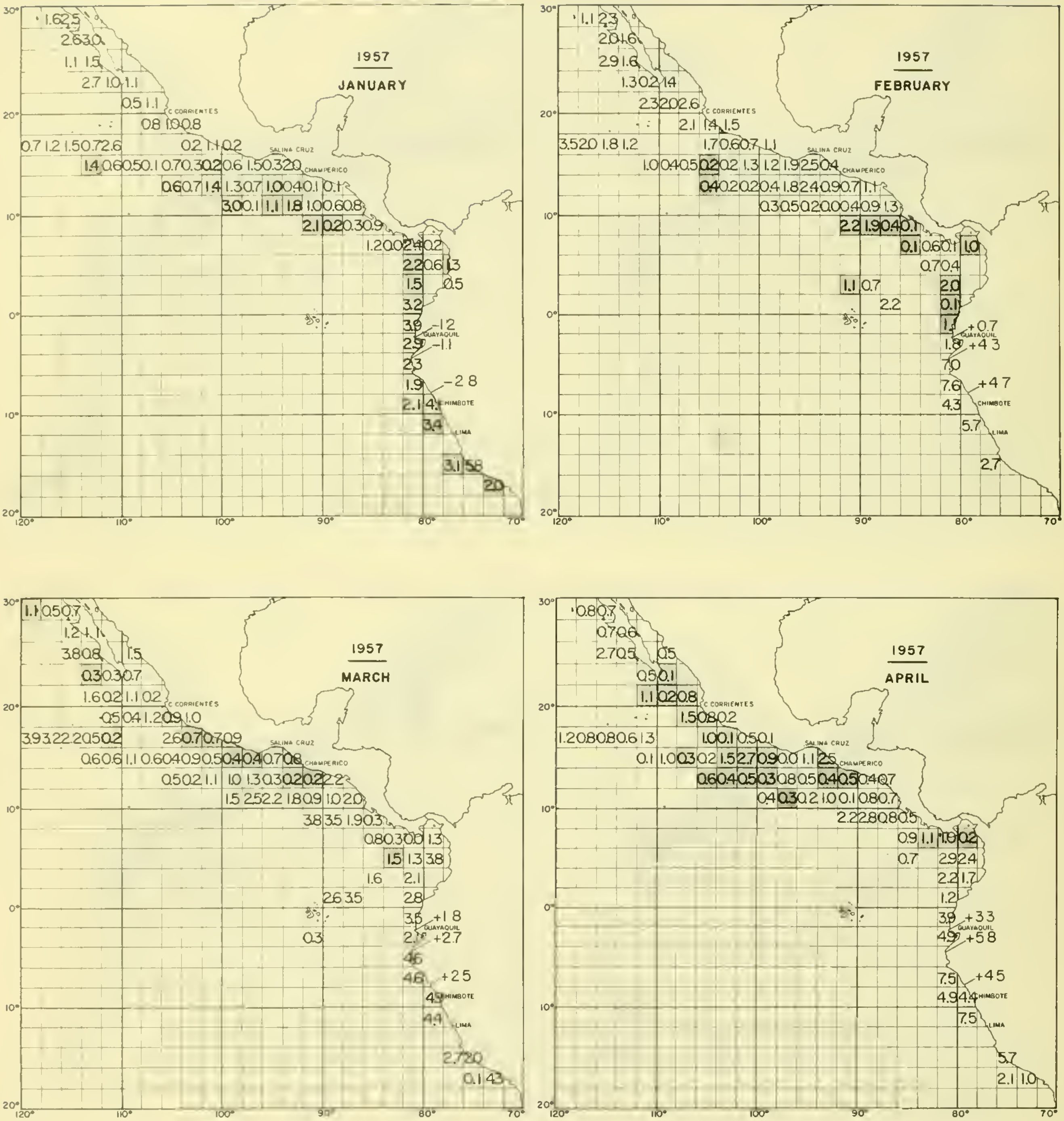
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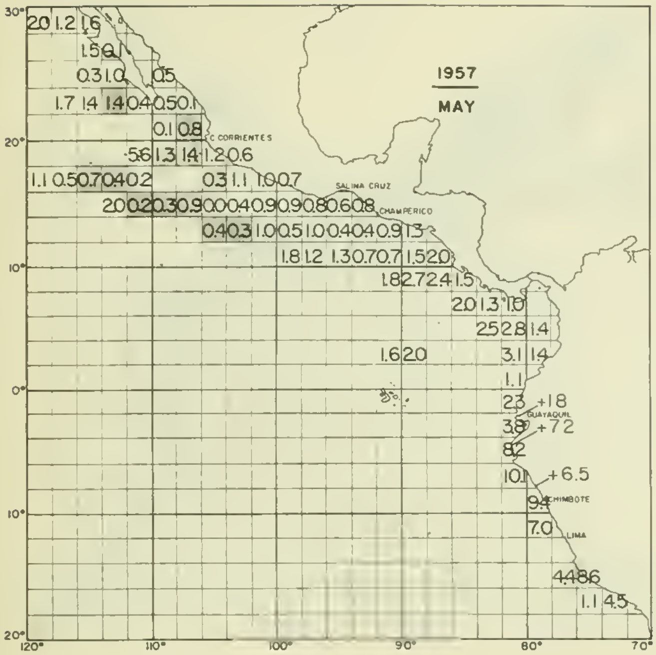
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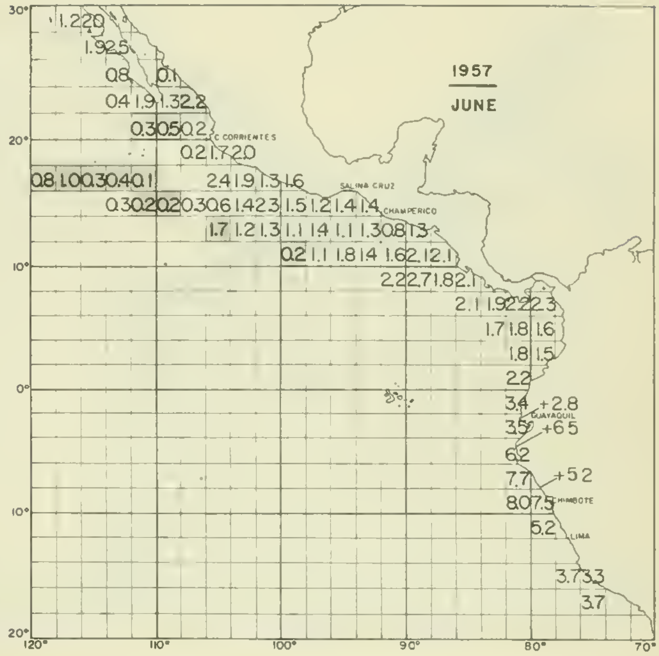
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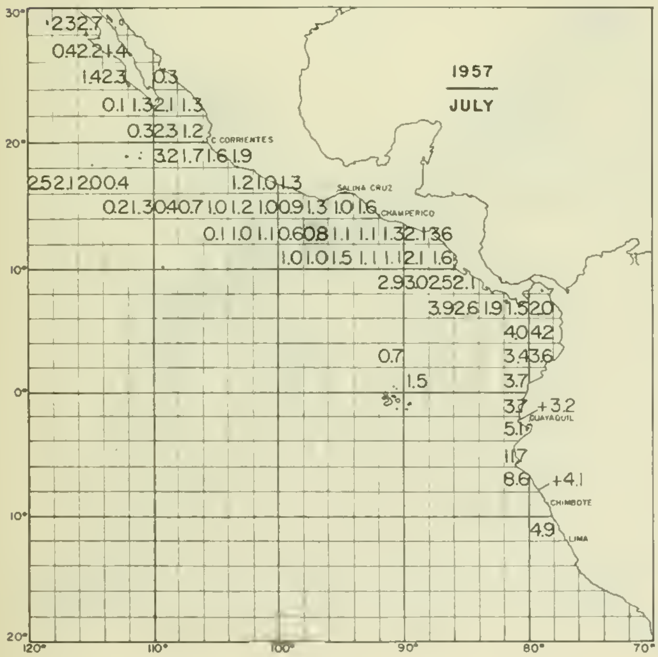
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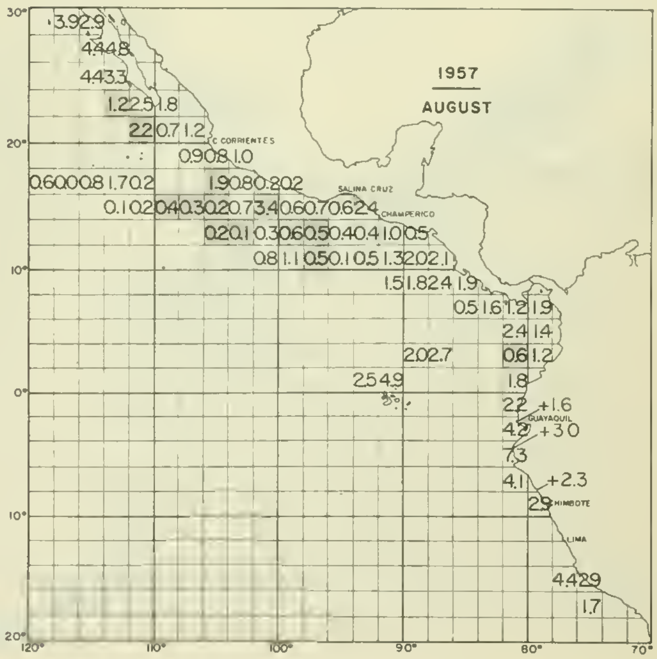
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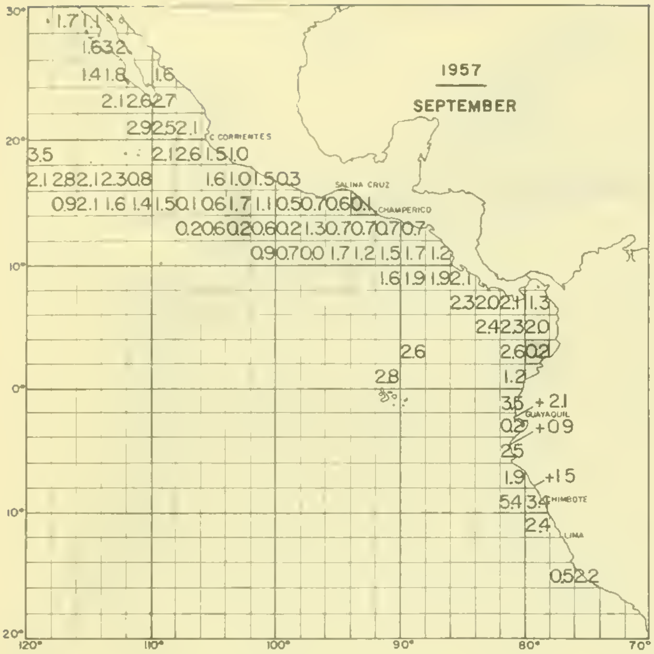
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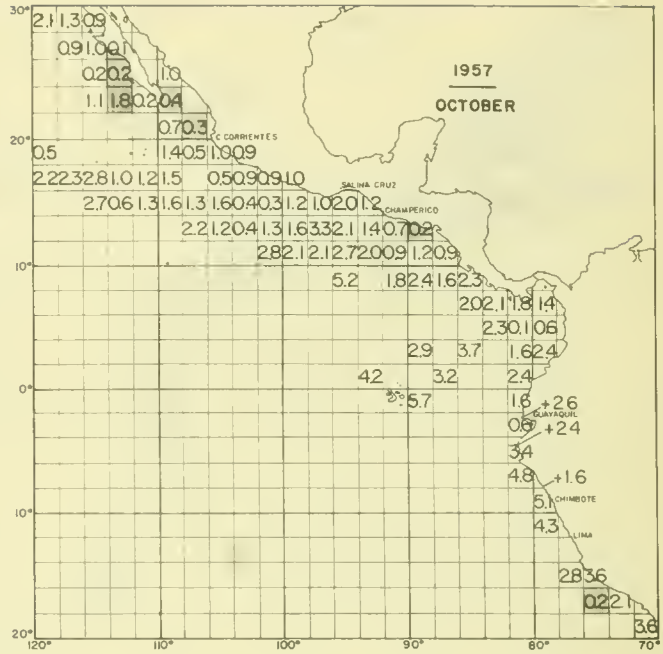
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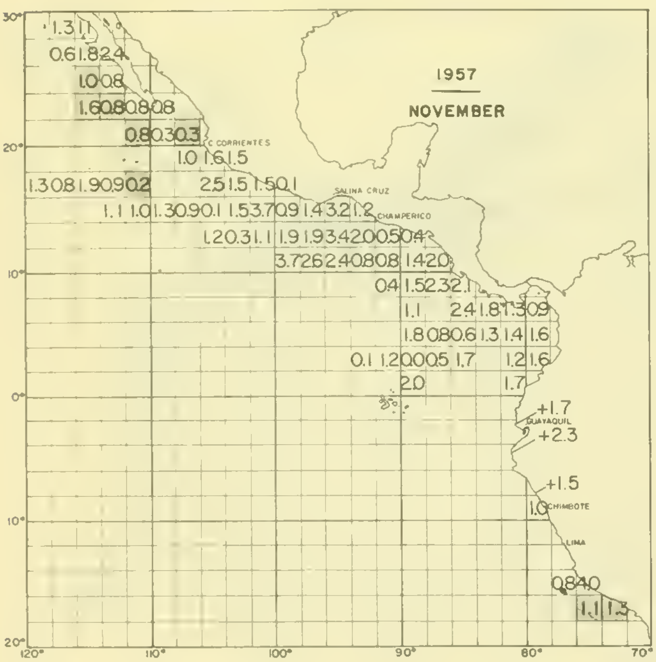
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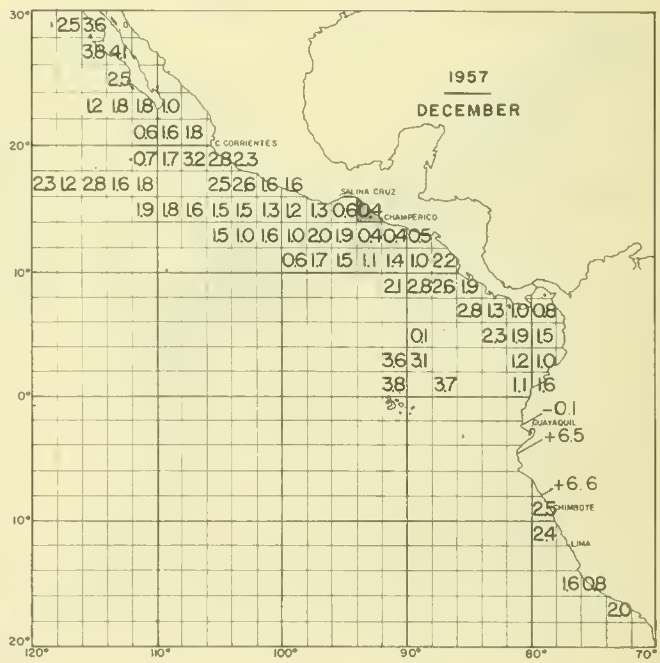
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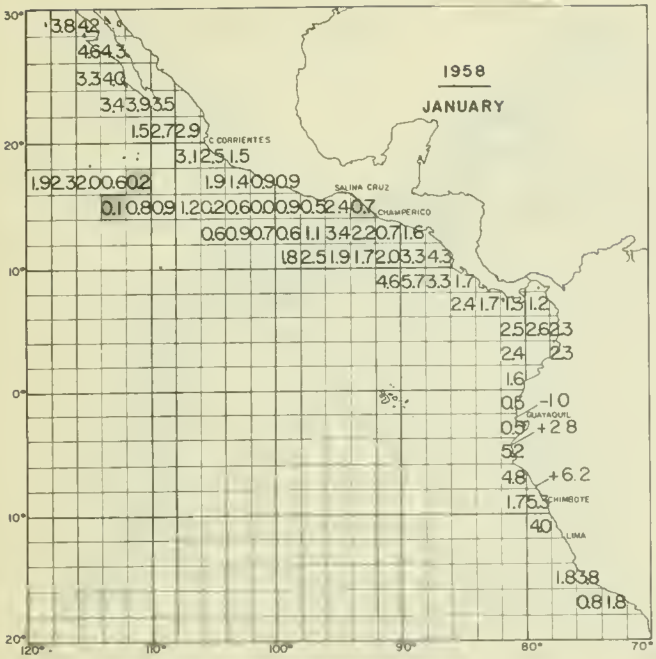
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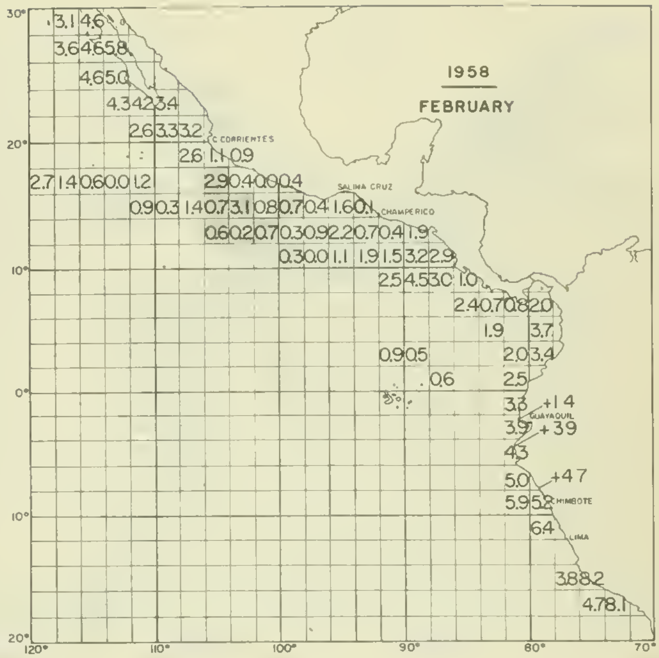
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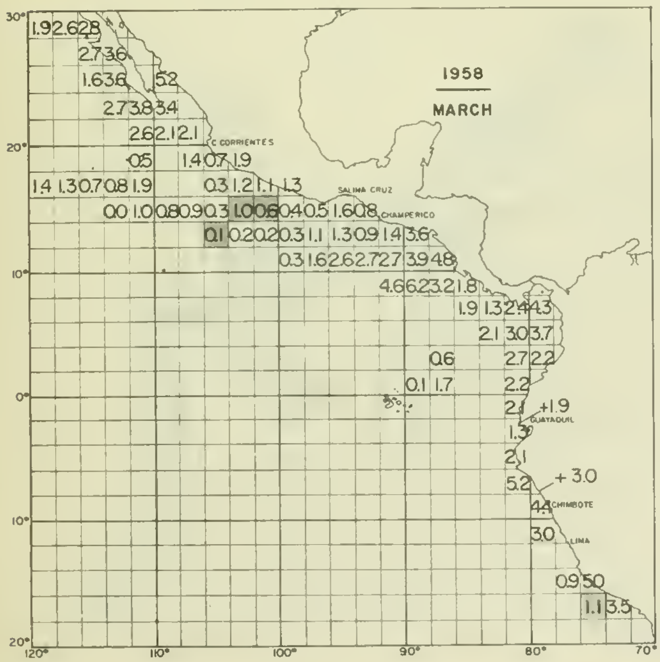
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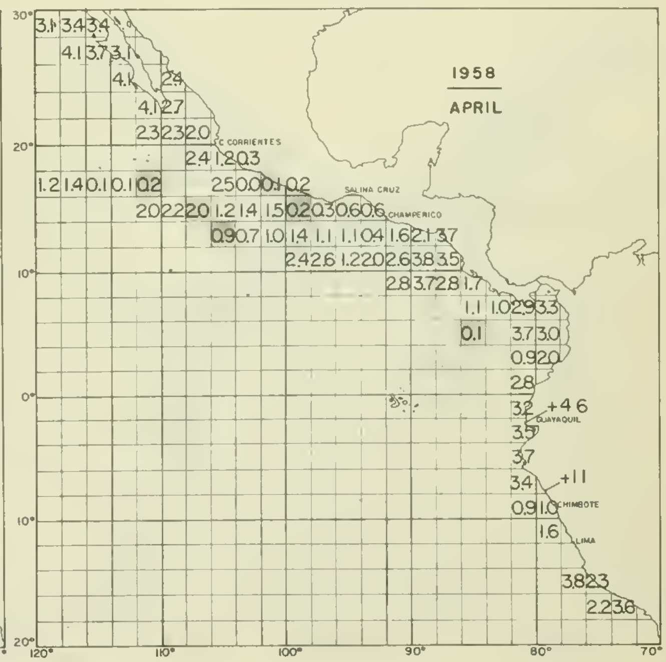
GUAYAQUIL
CHIMBOTE
LIMA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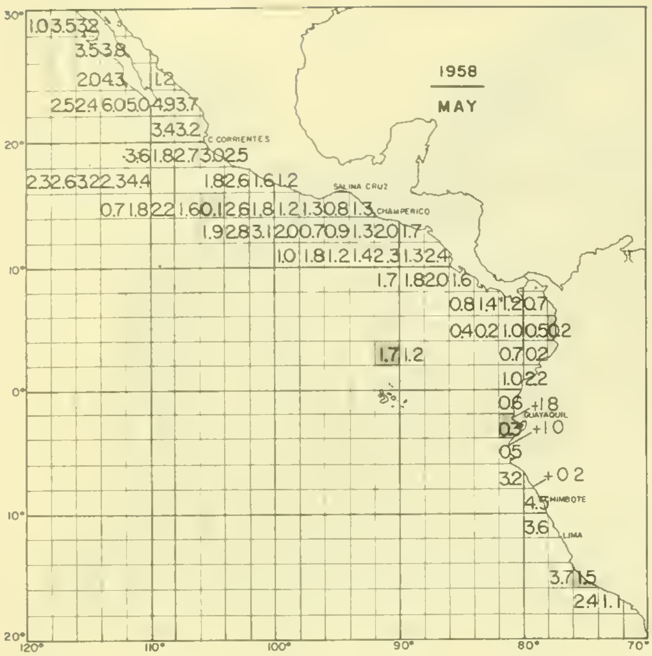
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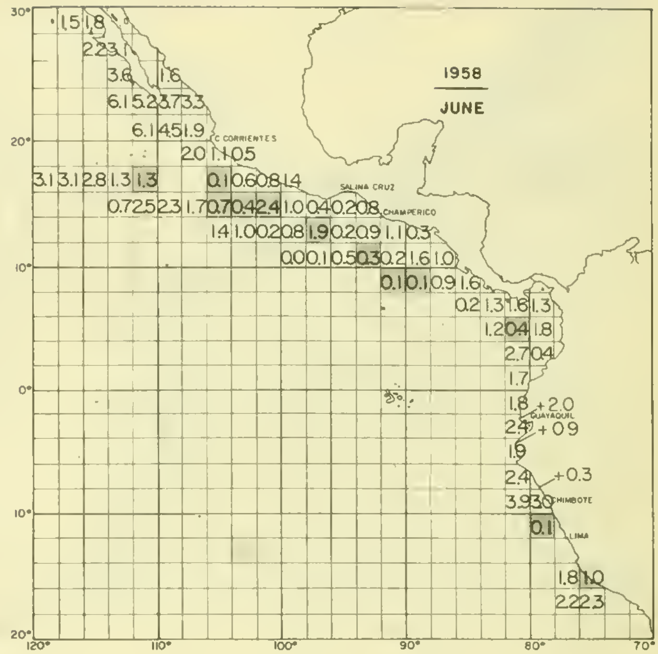
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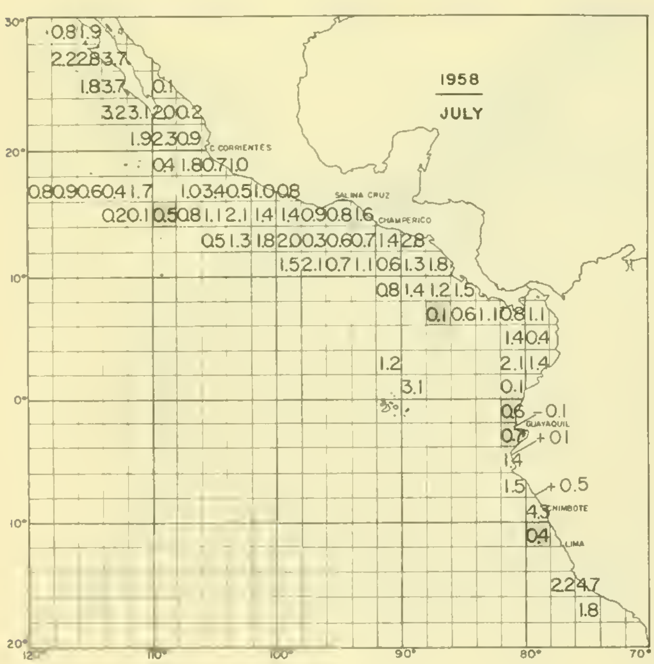
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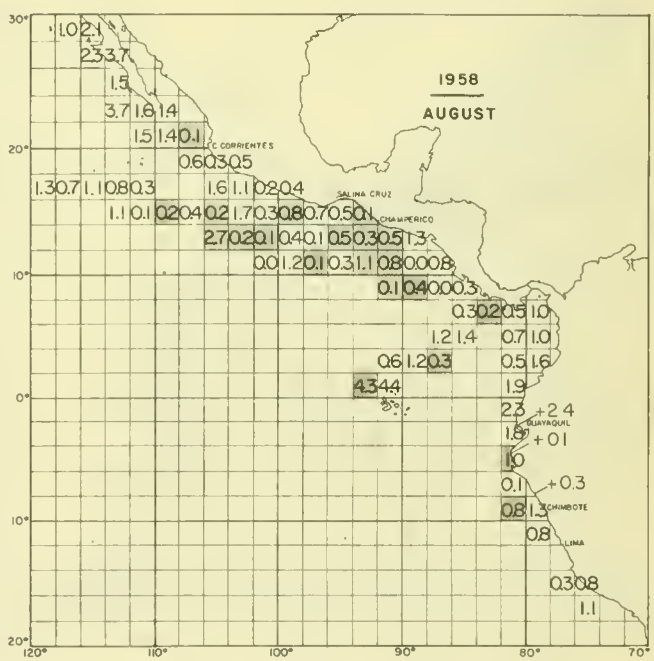
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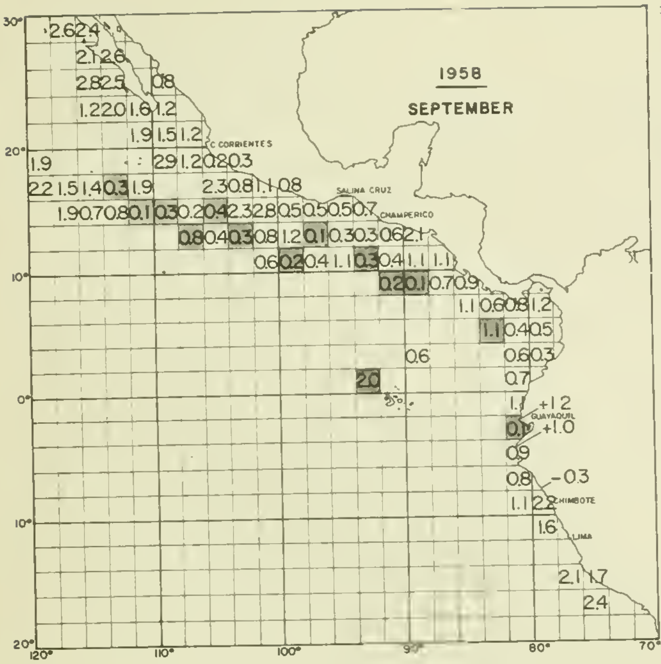

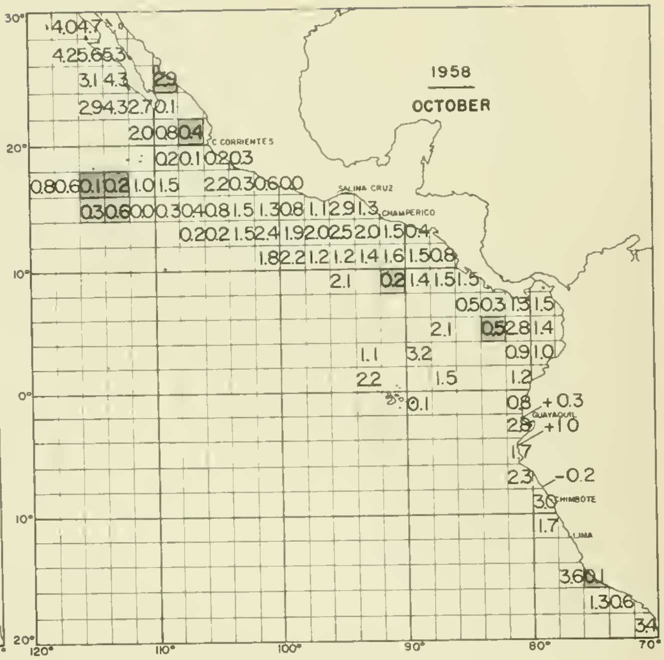

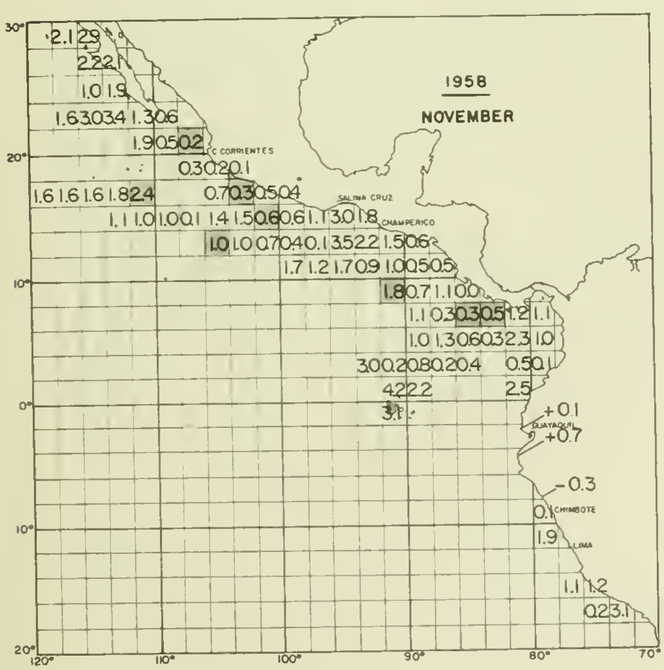

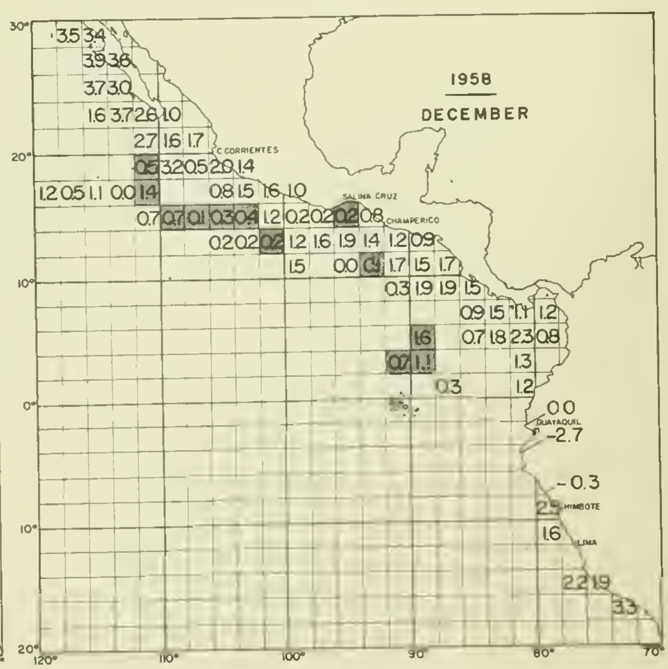

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As the Nation's principal conservation agency, the Department works to assure that nonrenewable resources are developed and used wisely, that park and recreational resources are conserved for the future, and that renewable resources make their full contribution to the progress, prosperity, and security of the United States--now and in the future.