

A Climatological Summary for Punta Cirio, Sonora, Mexico

Robert R. Humphrey

Department of Ecology and Evolutionary Biology
University of Arizona

Abstract

Climatological data have been collected at several stations in the general vicinity of Puerto Libertád, Sonora, Mexico at various intervals from 1925 to the present. The general area is a focal point for both research and teaching activities. For this reason and because the Sonoran Desert coastal climate is distinct from that of other portions of this desert, the data from these stations are here summarized and discussed. They are presented here primarily to make them available to future students of the area.

Introduction

Ecological studies of organic communities depend, even more than studies of individual species, on a knowledge of the prevailing environmental characteristics. When data of these kinds have not been obtained prior to initiating synecological research in a specific area it is often necessary to include time, effort and cost in collecting them to provide the environmental background for a particular study.

When research is carried out in well-known or long-settled areas most of the basic climatologic or other fundamental environmental information is usually available from various library sources. The more remote or sparsely populated the area of study, however, in general the fewer become the desired data and the more difficult they are to locate.

When few or no additional investigations are planned or likely in a specific locale there might be little or no justification for collating various kinds of environmental data. When, however, an area possesses unique characteristics or biota that give it unusual scientific interest a collation of this sort is of value, and is often justified.

Objective.—The object of this study is to summarize for future reference all meteorological data available for a restricted portion of the Gulf of California coast in Sonora, Mexico.

Time Interval Included.—Various time-span segments from 1925 through 1979 are included here although none of the records covers the entire 54-year interval.

Locale.—The meteorologic stations are located near the Gulf of California in the state of Sonora, Mexico. The northernmost was the Mexican government's station of Puerto Libertád, a small fishing village 250 km by air southwest of Nogales, Arizona. From Puerto Libertád the stations extended down the coast for some 24 km and inland for 9 km. Except for Puerto Libertád, all were located in a low coastal mountain range known as Sierra Cirio (Fig. 1).

Reason for Collating and Publishing the Data.—This area supports the only stand of cirios (boojum trees) (*Idria columnaris* Kellogg) growing on the mainland of Mexico. In addition, it provides a habitat for a variety of Sonoran Desert plants and animals with restricted distribution. Bordering the Gulf of Mexico, as it does, the climate is strongly marine influenced, thus presenting characteristics that are atypical of most of the Sonoran Desert and that have been largely or entirely unmeasured elsewhere along the Sonoran coast.

Punta Cirio early attracted the attention of workers from the Carnegie Desert Laboratory and the University of Arizona in Tucson. For many years, in part as a result of publications from these institutions, the region has become a kind of ecological classroom and laboratory for students from both in-state and out-of-state schools and museums. Both research and classwork are still active here and should continue to be long into the future. A knowledge of the region's climatic characteristics will be of value for both of these kinds of activities.

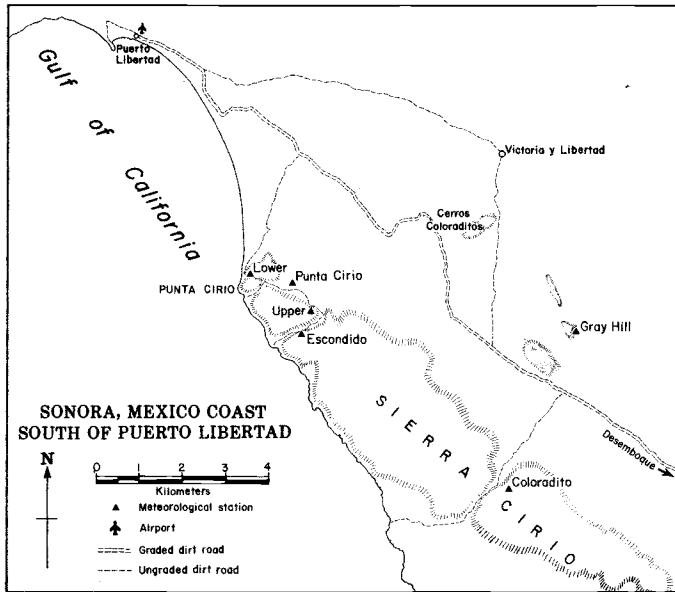


Figure 1. Map showing locations where climatological data were obtained.

Methods

Kinds of Data Collated Here.—Three kinds of meteorologic data are summarized here: precipitation, temperature and open-pan evaporation.

Meteorologic Stations.—The specific stations are here designated (1) Puerto Libertad—Mallery; (2) Puerto Libertad—Mexico; (3) Punta Cirio—Mallery; (4) Punta Cirio; (5) Lower; (6) Upper; (7) Escondido; (8) Gray Hill; and (9) Coloradito (Fig. 1 and Table 1).

The Carnegie Desert Laboratory had two rain gauges within the Puerto Libertad—Punta Cirio area (Mallery, 1936a, 1936b). These were established in April, 1935 as part of a series of 22 gauges that extended southwesterly from Tucson, Arizona to Puerto Libertad, Sonora and west from Tucson to a point 10 miles south of Wellton, Arizona, near Yuma. Data from the two gauges within the Puerto Libertad—Punta Cirio area were collected from April 1925 to December, 1935 and are summarized in Table 1.

During the period from November 26, 1967 to the present I have been recording precipitation data from the last six gauges listed in Table 2. These were tapered, plastic gauges sold under the TRU-CHEK brand name. They were read at irregular intervals but evaporation was prevented by pouring a small amount of lightweight motor oil into each after every reading. Each was mounted on the cut-off top of a cactus and so located as to be free of any obstruction that might affect collection of precipitation.

Four of these gauges were established in conjunction with four hygrothermographs designed to obtain data for another study (Humphrey & Marx, 1980).

Analysis

Mallery's winter rainfall season includes the months November through March; his summer season covers the

Table 1. Precipitation data from Carnegie Desert Laboratory in vicinity of Puerto Libertad, (1925–1935).

| Station | Average precipitation (mm) | | |
|---------------------|----------------------------|--------|--------|
| | summer | winter | annual |
| P. Libertad—Mallery | 62.0 | 40.0 | 102.0 |
| Punta Cirio—Mallery | 68.0 | 36.0 | 104.0 |

Table 2. Location and elevation of meteorologic stations.

| Station | Distance (km) air-line from P. Libertad | Distance (km) air-line from coast | Elevation above sea level (m) |
|---------------------|---|---|-------------------------------------|
| Libertad—Mallery | 0.02 | 0.02 | 31 |
| Libertad—Mexico | 0.0 | 0.01 | 7 |
| Punta Cirio—Mallery | 7.1 | 0.10 | 55 |
| Punta Cirio | 7.8 | 1.5 | 76 |
| Lower | 7.1 | 0.15 | 12 |
| Upper | 8.9 | 1.6 | 162 |
| Escondido | 9.4 | 0.8 | 85 |
| Gray Hill | 14.7 | 7.4 | 198 |
| Coloradito | 16.2 | 2.9 | 303 |

balance of the year, April through October (Mallery, 1936a). Using this seasonal breakdown, Mallery noted that 39% of the Libertad precipitation fell during the winter, versus 61% in the summer. His Punta Cirio data were rather similar: 35% in the winter and 65% in the summer. A similar analysis of the longer-period Puerto Libertad—Mexico data resulted in a more nearly equal seasonal breakdown: 47% winter and 53% summer (Secretaría de Recursos Hidráulicos, 1961–1976).

In contrast with this slight disparity in favor of the summer season the winter rains are, with little question, much more effective as a factor affecting plant growth than those of the summer. Two factors appear to be of prime importance in this: (a) the summer period has markedly higher temperatures and consequently lower relative humidity than the winter; and (b) the summer rains occur largely as intense short-period storms, with much of the precipitation often lost by runoff and evaporation, in comparison with lower-intensity, longer-duration rains during the winter, a much greater percentage of which is usually absorbed and retained by the soil.

Although the summer analysis includes a longer period than the winter (7 mos. vs 5 mos.) three of the summer months, April, May and June, receive no effective rainfall. Only once, in the 16 years of record included in the Puerto Libertad—Mexico data of Table 3, did any rain fall during April. This yielded an average of only 0.2 mm; May received rain only twice (average 0.9 mm); and although a measurable amount fell once during June, this was so little as to average out at only 0.125 mm for the 16 years of record.

Both the evaporation and temperature records at Puerto Libertad—Mexico support the foregoing observations regarding relative effectiveness of the summer and winter rains. Employing the same monthly breakdowns, the mean-monthly winter and summer evaporation records (Table 4) show 126 mm per month during the winter vs 242 mm during the summer, ie—twice as high in the

Table 3. Precipitation (mm) at Puerto Libertád—Mexico.

| Year | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. | Annual |
|-------|------|------|------|------|-----|------|------|------|------|------|------|------|--------|
| 1961 | 50 | 0 | 0 | 0 | 0 | 2 | 0 | 0 | 0 | 6 | 3 | 36 | 97 |
| 1962 | 52 | T | 2 | 0 | 0 | NR* | 0 | T | 28 | 0 | 0 | 38 | 120 |
| 1963 | 2 | 0 | 0 | 0 | 0 | 0 | 0 | 46 | 0 | 33 | 8 | 0 | 89 |
| 1964 | 2 | 23 | 4 | 0 | 0 | 0 | 18 | 5 | 0 | 57 | 14 | NR | 117 |
| 1965 | 0 | 8 | 0 | 3 | 0 | 0 | 9 | 0 | 0 | 0 | 0 | 56 | 76 |
| 1966 | 27 | 12 | 0 | 0 | 0 | 0 | 0 | 0 | 59 | 9 | 0 | 16 | 123 |
| 1967 | 0 | 0 | 2 | 0 | 0 | 0 | 7 | 48 | 10 | 30 | 27 | 43 | 167 |
| 1968 | 3 | 3 | 3 | 0 | 0 | 0 | 0 | 23 | 0 | 0 | 6 | 0 | 38 |
| 1969 | 30 | 0 | 3 | 0 | 14 | 0 | 21 | 16 | 18 | T | 19 | 6 | 127 |
| 1970 | 2 | 10 | 0 | 0 | 0 | 0 | 25 | 11 | 13 | 0 | 0 | 0 | 61 |
| 1971 | 0 | 10 | 0 | 0 | 0 | 0 | 0 | 20 | 6 | 0 | 12 | 8 | 56 |
| 1972 | 0 | 0 | 0 | 0 | 0 | 0 | 4 | 28 | 0 | 73 | 14 | 1 | 120 |
| 1973 | 0 | 37 | 0 | 0 | 1 | 0 | 0 | 2 | 0 | 0 | 0 | 0 | 40 |
| 1974 | 16 | 0 | 2 | 0 | 0 | 0 | 2 | 0 | 10 | 3 | 0 | 0 | 33 |
| 1975 | NR | 0 | 6 | 0 | 0 | 0 | 5 | T | 14 | 1 | 0 | 2 | 26 |
| 1976 | 0 | 2 | 0 | 0 | 0 | 0 | 3 | 1 | 18 | 1 | 9 | 2 | 36 |
| Total | 184 | 105 | 22 | 3 | 15 | 0 | 94 | 200 | 176 | 213 | 112 | 202 | 1,326 |
| Ave. | 12.3 | 6.6 | 1.4 | 0.2 | 0.9 | 0.0 | 5.9 | 13.3 | 11.0 | 13.3 | 7.0 | 13.9 | 82.9 |

*NR—No record.

Table 4. Evaporation (mm) at Puerto Libertád—Mexico

| Year | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. | Annual |
|-------|--------------|--------------|--------------|--------------|--------------|---------------|--------------|--------------|--------------|--------------|--------------|--------------|--------|
| 1961 | 71.7 | 127.5 | 157.4 | 216.8 | 236.9 | 233.1 | 275.3 | 231.4 | 229.5 | 185.3 | 127.9 | 75.3 | 2168.1 |
| 1962 | 108.9 | 93.4 | 147.5 | 202.7 | 236.7 | <u>234.8*</u> | 281.2 | 250.8 | 209.7 | 184.9 | 158.0 | 91.0 | 2199.6 |
| 1963 | 82.3 | 140.3 | 164.5 | 174.8 | 271.0 | 252.3 | <u>258.2</u> | <u>262.0</u> | <u>233.0</u> | 146.9 | 141.2 | 85.3 | 2211.8 |
| 1964 | 70.1 | 68.1 | <u>172.3</u> | <u>196.5</u> | <u>236.2</u> | <u>234.8</u> | <u>258.2</u> | <u>262.0</u> | <u>233.0</u> | <u>192.7</u> | <u>138.3</u> | <u>102.6</u> | 2164.8 |
| 1965 | <u>101.5</u> | <u>116.0</u> | <u>172.3</u> | <u>196.5</u> | 229.9 | <u>234.8</u> | <u>267.6</u> | 251.1 | 232.4 | 207.5 | 129.3 | 121.0 | 2259.9 |
| 1966 | 107.2 | 116.3 | <u>172.3</u> | <u>196.5</u> | <u>236.2</u> | <u>234.8</u> | 295.6 | 246.0 | 204.2 | 188.5 | 127.7 | 113.3 | 2238.6 |
| 1967 | 106.7 | 138.8 | 173.5 | 193.1 | 252.5 | 225.3 | 232.8 | 271.0 | 224.3 | 164.0 | 106.9 | 70.4 | 2159.3 |
| 1968 | 93.1 | 101.3 | 159.8 | <u>196.5</u> | 159.1 | 150.1 | 150.8 | 238.9 | 242.0 | 209.4 | 167.1 | 95.8 | 1963.9 |
| 1969 | 117.4 | 129.3 | 136.4 | <u>196.5</u> | 329.1 | 329.4 | 312.4 | 319.2 | 240.3 | 198.8 | 119.1 | 97.7 | 2525.6 |
| 1970 | 100.2 | 115.4 | 257.6 | 263.5 | 274.9 | 262.6 | 276.3 | 272.7 | 259.5 | 217.1 | 128.0 | 111.1 | 2538.9 |
| 1971 | 120.8 | 129.8 | 188.7 | 164.6 | 215.3 | 228.9 | 251.7 | 245.4 | 250.3 | 255.2 | 138.6 | 160.1 | 2349.4 |
| 1972 | 138.3 | 116.0 | 165.5 | 160.2 | 156.8 | 196.7 | 238.8 | 293.1 | 237.7 | 162.1 | 177.5 | 107.7 | 2150.4 |
| Total | 1218 | 1392 | 2068 | 3341 | 2835 | 2818 | 3099 | 3144 | 2796 | 2312 | 1660 | 1231 | |
| Mean | 101.5 | 116.0 | 172.3 | 278.4 | 236.2 | 234.8 | 258.2 | 262.0 | 233.0 | 192.7 | 138.3 | 102.6 | |

*Underlining indicates extrapolated data obtained by averaging the recorded observations and using this mean as the best approximation of the missing records.

Table 5. Mean Monthly Temperatures (°C) at Puerto Libertád—Mexico.

| Year | Jan. | Feb. | Mar. | Apr. | May | June | July | Aug. | Sep. | Oct. | Nov. | Dec. | Annual |
|-----------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|-------|--------|
| 1961 | 14.0 | 14.0 | 14.7 | 18.4 | 20.5 | 25.7 | 27.8 | 28.5 | 26.9 | 20.9 | 15.9 | 13.5 | |
| 1962 | 12.3 | 14.1 | 12.4 | 21.0 | 22.9 | — | 28.8 | 30.2 | 28.3 | 22.8 | 19.0 | 15.1 | |
| 1963 | 11.7 | 15.1 | 14.6 | 17.6 | 22.7 | 22.8 | 29.2 | 29.2 | 28.3 | 24.3 | 17.6 | 13.8 | |
| 1964 | 10.8 | 11.2 | 13.6 | 17.4 | 20.1 | 23.9 | 29.2 | 28.8 | 27.3 | 24.7 | 20.1 | — | |
| 1965 | 13.0 | 13.0 | 13.4 | 17.4 | 19.8 | 21.6 | 28.2 | 29.5 | 27.0 | 23.0 | 19.4 | 15.0 | |
| 1966 | 12.1 | 11.9 | 15.2 | 19.2 | 23.5 | 22.2 | 29.5 | 30.0 | 28.8 | 21.4 | 17.7 | 13.4 | |
| 1967 | 10.8 | 13.9 | 15.6 | 15.7 | 21.2 | 22.9 | 29.4 | 29.3 | 27.3 | 23.3 | 19.2 | 11.2 | |
| 1968 | 12.5 | 15.2 | 15.8 | 19.4 | 20.1 | 24.8 | 30.0 | 27.8 | 26.6 | 21.6 | 17.2 | 17.6 | |
| 1969 | 13.6 | 12.8 | 13.8 | 18.4 | 22.0 | 24.8 | 28.9 | 30.8 | 29.0 | 21.0 | 16.6 | 12.7 | |
| 1970 | 11.7 | 13.6 | 14.6 | 15.6 | 20.8 | 23.9 | 29.1 | 29.9 | 26.7 | 20.3 | 16.1 | 13.0 | |
| 1971 | 10.0 | 11.8 | 14.6 | 16.2 | 19.3 | 23.5 | 28.9 | 28.9 | 27.5 | 20.2 | 15.1 | 11.8 | |
| 1972 | 10.6 | 13.2 | 16.9 | 17.5 | 21.1 | 24.8 | 29.3 | 28.2 | 26.5 | 22.1 | 15.3 | 12.4 | |
| 1973 | 11.5 | 14.2 | 13.5 | 16.0 | 21.2 | 27.7 | 28.2 | 28.6 | 25.9 | 21.1 | 16.4 | 11.8 | |
| 1974 | 12.4 | 13.0 | 16.8 | 19.4 | 20.8 | 23.2 | 24.1 | 24.5 | 24.7 | 20.4 | 15.5 | 11.2 | |
| 1975 | 11.7 | 12.8 | 14.8 | 15.3 | 20.5 | 24.9 | 29.4 | 30.0 | 29.7 | 21.6 | 16.2 | 12.2 | |
| 1976 | 14.1 | 12.9 | 15.3 | 18.8 | 23.5 | 23.5 | 27.5 | 28.9 | 25.7 | 22.2 | 16.1 | 13.5 | |
| Total | 192.8 | 212.7 | 235.6 | 283.3 | 340.0 | 360.2 | 457.5 | 463.1 | 436.2 | 350.0 | 273.4 | 198.2 | |
| Mean (°C) | 12.0 | 13.3 | 14.7 | 17.7 | 21.3 | 24.0 | 28.6 | 28.9 | 27.3 | 21.9 | 17.1 | 13.2 | |

Table 6. Precipitation (mm) of Humphrey Sonoran Coast Rain Gauges

| Date read | Lower | Punta Cirio | Upper | Escondido | Gray Hill | Coloradito | Period Total | Period Mean |
|-----------|-----------|-------------|-----------|-----------|-----------|------------|--------------|-------------|
| 11-26-67 | Installed | | Installed | | | | | |
| 2-15-68 | 140.97 | | 152.4 | | | | 293.37 | 146.7 |
| 4-14-68 | 20.32 | | 17.78 | | | | 38.10 | 19.0 |
| 6-15-68 | 0.0 | | 0.0 | | | | 0.0 | 0.0 |
| 8-16-68 | 6.35 | | 10.92 | | | | 17.27 | 8.6 |
| 10-15-68 | 3.81 | | 1.01 | | | | 4.82 | 2.4 |
| 12-30-68 | 5.08 | | not read | | | | 5.08 | 2.5 |
| Total | 176.53 | | 182.11 | | | | | |
| 3-27-69 | 15.24 | | 20.32 | | | | 35.56 | 17.8 |
| 7-25-69 | 3.30 | | 5.33 | | | | 8.63 | 4.3 |
| Total | 18.54 | | 25.65 | | | | | |
| 2-14-70 | 17.78 | | 92.71 | | | | 110.49 | 55.2 |
| 7-22-70 | 27.94 | | 24.13 | | | | 52.07 | 26.0 |
| 8-26-70 | 19.30 | | 12.70 | | | | 32.00 | 16.0 |
| 11-28-70 | 36.83 | | 35.56 | | | | 72.39 | 36.2 |
| 12-18-70 | 0.0 | | 0.0 | | | | 0.0 | 0.0 |
| Total | 138.93 | | 216.40 | | | | | |
| 3- 9-71 | 6.60 | | 4.57 | | | | 11.17 | 5.6 |
| 9- 6-71 | 59.69 | | 53.34 | | | | 113.03 | 56.5 |
| 12-13-71 | 27.94 | | 23.36 | | | | 51.30 | 25.6 |
| Total | 94.23 | | 81.27 | | | | | |
| 6-11-72 | 4.57 | Installed | 4.57 | | | | 9.14 | 4.5 |
| 8-5-72 | 0.76 | 0.60 | 1.77 | | | | 3.13 | 1.0 |
| 9- 6-72 | 39.87 | 29.97 | 21.08 | | | | 90.92 | 30.3 |
| 10- 8-72 | 31.75 | 27.94 | 21.33 | | | | 81.02 | 27.0 |
| 11-11-72 | 40.64 | 45.72 | 40.64 | | | | 127.00 | 42.3 |
| 12-11-72 | 5.84 | 5.58 | 4.31 | | | | 15.73 | 5.2 |
| Total | 123.43 | 109.72 | 93.70 | | | | | |
| 1-11-73 | 3.55 | 3.55 | 3.55 | | | | 10.65 | 3.5 |
| 2-11-73 | 4.82 | 5.84 | 5.08 | | | | 15.74 | 5.2 |
| 3-11-73 | 38.10 | 36.83 | 34.29 | Installed | Installed | Installed | 109.22 | 36.4 |
| 4-10-73 | 17.78 | 22.86 | 16.00 | 19.05 | 15.24 | 11.68 | 102.61 | 17.1 |
| 5-10-73 | 17.78 | 10.66 | 10.66 | 9.90 | 15.24 | 11.68 | 75.92 | 12.6 |
| 6- 7-73 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7- 6-73 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8- 3-73 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8-25-73 | 0.0 | 0.0 | 0.50 | 0.50 | 0.0 | 1.52 | 2.52 | 0.4 |
| 9-21-73 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 10-20-73 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 11-18-73 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 12-12-73 | 2.79 | 2.54 | 1.52 | 0.25 | 3.04 | 4.06 | 14.20 | 2.4 |
| 12-28-73 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total | 84.82 | 82.28 | 71.60 | 29.70 | 33.52 | 28.94 | | |
| 1-25-74 | 24.13 | 26.67 | 25.40 | 20.06 | 29.21 | 26.67 | 152.14 | 25.3 |
| 2-22-74 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 3-21-74 | 8.63 | 12.44 | 12.70 | 5.08 | 9.14 | 13.20 | 61.19 | 10.2 |
| 4-25-74 | 0.76 | 0.50 | 0.0 | T | 0.76 | 0.60 | 2.62 | 0.4 |
| 5-21-74 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6-21-74 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7-18-74 | 4.06 | 4.06 | 4.06 | 2.79 | 4.31 | 2.79 | 22.07 | 3.7 |
| 8-15-74 | 0.0 | 5.58 | 12.95 | 8.12 | 7.11 | 7.11 | 40.87 | 6.8 |
| 9-12-74 | 0.0 | 0.50 | 0.76 | 0.76 | 0.50 | 1.01 | 3.53 | 0.6 |
| 10-13-74 | 2.03 | 3.04 | 2.03 | 2.03 | 0.50 | 0.76 | 8.36 | 1.4 |
| 11-16-74 | 0.0 | 3.81 | 2.54 | 2.03 | 0.76 | 1.01 | 10.15 | 1.7 |
| 12-21-74 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total | 39.61 | 56.60 | 60.44 | 40.87 | 52.29 | 53.15 | | |
| 1-20-75 | 5.84 | 7.36 | 7.11 | 6.85 | 6.35 | 7.62 | 41.13 | 6.8 |
| 2-17-75 | 1.52 | 2.03 | 0.76 | 1.27 | 2.03 | .05 | 7.66 | 1.3 |
| 3-17-75 | 6.85 | 7.62 | 6.85 | 5.58 | 12.70 | 8.12 | 47.72 | 7.9 |

Table 6. (continued)

| Date read | Lower | Punta Cirio | Upper | Escondido | Gray Hill | Coloradito | Period Total | Period Mean |
|-----------------------------|---------|-------------|---------|-----------|-----------|------------|--------------|-------------|
| 4-13-75 | 0.76 | 1.01 | 6.35 | 0.76 | 0.50 | 0.76 | 10.14 | 1.7 |
| 5-11-75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 6- 8-75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 7- 7-75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| 8- 4-75 | 3.55 | 5.08 | 3.30 | 2.54 | 10.66 | 5.08 | 30.21 | 5.0 |
| 9- 2-75 | 0.0 | 0.0 | 0.0 | 0.0 | 1.01 | 0.0 | 1.01 | 0.2 |
| 10- 1-75 | 0.0 | 0.0 | 0.0 | 0.0 | 5.84 | 7.87 | 13.71 | 2.3 |
| 10-28-75 | 2.28 | 0.76 | 0.0 | 0.0 | 0.0 | 0.0 | 3.04 | 0.5 |
| 11-24-75 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 | 0.0 |
| Total | 20.80 | 23.86 | 24.37 | 17.00 | 39.09 | 29.50 | | |
| 4-12-76 | 22.86 | 25.4 | 13.97 | 16.25 | 35.56 | 24.13 | 138.17 | 23.0 |
| 7-26-76 | 5.84 | 10.16 | 16.76 | 3.81 | 11.68 | 6.60 | 54.85 | 9.1 |
| 10-24-76 | 21.33 | 33.02 | 23.87 | 25.40 | 76.20 | 26.67 | 206.49 | 34.4 |
| 12-23-76 | 5.58 | 12.95 | 9.65 | 8.63 | 21.33 | 17.78 | 75.92 | 12.6 |
| Total | 55.61 | 81.53 | 64.25 | 54.09 | 144.77 | 75.18 | | |
| 4-11-77 | 31.75 | 33.02 | 28.44 | 30.48 | 53.34 | 35.56 | 212.59 | 35.4 |
| 10-24-77 | 46.99 | 43.18 | 39.37 | 38.10 | 64.77 | 55.88 | 288.29 | 48.0 |
| Total | 78.74 | 76.20 | 67.81 | 68.58 | 118.11 | 91.44 | | |
| 1-25-78 | 31.49 | 31.75 | 24.13 | 26.67 | 31.75 | 26.67 | 172.46 | 28.7 |
| 5- 2-78 | 40.64 | 50.80 | 48.26 | 35.56 | 66.04 | 60.96 | 302.26 | 50.4 |
| 8- 4-78 | 17.78 | 12.70 | 8.63 | 8.63 | 25.40 | 23.36 | 96.50 | 16.1 |
| 10-19-78 | 1.27 | 1.77 | 1.01 | 1.01 | 0.0 | 1.01 | 6.07 | 1.0 |
| 1- 6-79 | 114.30 | 116.84 | 110.49 | 101.60 | 158.75 | 135.89 | 737.87 | 123.0 |
| Total | 205.48 | 213.86 | 192.52 | 173.47 | 281.94 | 247.89 | | |
| 4- 6-79 | 46.99 | 54.61 | 46.48 | 38.10 | 69.85 | 52.07 | 308.10 | 51.3 |
| 5-18-79 | 2.54 | 2.54 | 1.27 | 1.27 | 1.27 | 2.54 | 11.43 | 1.9 |
| 11-14-79 | 59.69 | 54.61 | 40.64 | 34.29 | 33.02 | 30.48 | 252.73 | 42.1 |
| Total | 109.22 | 111.76 | 88.39 | 73.66 | 104.14 | 85.09 | | |
| Grand Total | 1033.17 | 755.81 | 1061.59 | 457.37 | 773.86 | 611.19 | | |
| Divisor | 11.97 | 7.40 | 11.97 | 6.68 | 6.68 | 6.68 | | |
| Mean Annual | 86.31 | 102.13 | 88.68 | 68.46 | 115.84 | 91.49 | | |
| Overall Mean Annual Average | | | | | | | | 92.15 |
| Deviation | -5.84 | +9.98 | -3.47 | -23.69 | +23.69 | -0.66 | | |

summer as in the winter. The mean-monthly winter: summer temperature differences (Table 5) show a similar effect: a winter mean of 14°C vs a summer mean of 24°C.

Because my six gauges were read in part at intervals that do not coincide with seasons, the resultant precipitation data do not lend themselves as a whole to the same kind of seasonal analysis as those of Mallery and the Departamento de Hydrometría. They do, however, show several precipitation characteristics that are of interest.

These six gauges, separated from each other as they are, by distances ranging from 1.35 to 6 km, and ranging in elevation above sea level from 12 to 303 meters provide, and will continue to provide, a unique record of precipitation-distribution data for this area.

Although all the gauges were not in operation for identical time periods (three for 6.68 years, one for 7.40 and two for 11.97), a fact that could affect the results somewhat, a comparison of the mean-annual rainfall at the various locations is of interest.

The six stations have an average mean-annual precipi-

tation of 92.15 mm with deviations around this mean of -5.84, +9.98, -3.47, -23.69, +23.69 and -0.66 for the various gauges in the order in which they are listed in Table 6. It might be expected that these deviations would bear some consistent relationship either to elevation or to distance from the gulf, but this did not prove to be the case.

Although minor deviations from the overall mean-annual average are to be expected and may not indicate real, long-time differences, the departures for both Escondido and Gray Hill exceed what might be considered as minor, insignificant values. Escondido, for example, averaged 23.69 mm less than average, while nearby Punta Cirio exceeded the average by 9.98 mm. Yet these gauges were separated spatially by only about 1.5 km, both were essentially equidistant from the gulf, at about the same elevation, and both were on the north slope and near the base of individual mountain segments.

The markedly lighter rainfall at Escondido cannot be attributed to one or a few individual low-intensity storms,

Table 7. Statistical analysis of differences in precipitation amounts between stations.

| | Punta | | | Gray | |
|-------------------------|-------|--------|-------|-----------|--------|
| | Lower | Cirio | Upper | Escondido | Hill |
| Lower | 2.43 | 12.63 | 0.30 | 0.26 | 1.89 |
| Punta Cirio | | 0.01 | 0.00 | 1.24 | 45.10 |
| Upper | | | 0.92 | 1.27 | 2.56 |
| Escondido | | | | 0.02 | 0.07 |
| Gray Hill | | | | | 0.07 |
| Mean Annual Precip (mm) | 86.31 | 102.13 | 88.68 | 68.46 | 115.84 |
| | | | | | 91.49 |

since the amount recorded there was consistently less than at Punta Cirio. During the period April 10, 1973 to November 14, 1979 both gauges were read 49 times at intervals of approximately one month or longer. Seventeen of these readings recorded no rain in either gauge. During 29 of the remaining 32, or 90% of the time, however, Punta Cirio received more precipitation than Escondido.

This raises the question: are there local, sometimes proximate relatively dry "pockets" where precipitation may be markedly less than the norm? This analysis would suggest an affirmative answer. Indeed, in an extremely rugged terrain of the sort encountered here, differences of this sort, rather than essential uniformity, might readily be the norm.

In contrast with the deficiency noted at Escondido, it will be seen that the amount received at Gray Hill coincidentally exceeded the overall average by the exact amount that Escondido fell below it.

A study of Table 6 suggests that this positive deviation is due more to occasional periods of heavier than usual rainfall than to consistent precipitation differences. A marked excess at Gray Hill over the amount received in any of the other gauges occurred only 5 times: in the readings of 3-17-75, 8-4-75, 4-11-77 and 1-6-79.

The period of record is too short to conclude that the area represented by Gray Hill does have a true, long-time average greater than that of any of the sites closer to the coast, but this is suggested. The gauge is located in a wide inland basin, about 5 km northeast of the crest of the Sierra Cirio. Convection currents may influence the amount of precipitation received here as the moist air rises and is carried inland over the mountains.

A precipitation characteristic brought out by the Puerto Libertad-Mexico record (Table 3) as well as by my six gauges (Table 6) is the long duration of totally rainless periods or of periods with no effective rainfall. Note, for example, that there was no effective precipitation at Puerto Libertad from February until December 1961; from February through August, 1962; and from January through July, 1963. Several other of the 16 years during the period from 1961 through 1976 were almost as dry and may have received no effective rains for equally long periods.

Severe droughts may be protracted, covering several years. Note, for example, that during the period from 1973-1976 the total annual precipitation at Puerto Libertad ranged from a minimum of 26 mm (1.02 in.) to a

maximum of 40 mm (1.57 in.). The effect of a protracted drought of this severity can be devastating to both plant and animal life, even in an ecosystem that has developed through unknown millenia under stresses of this sort. Nonetheless, in an area where the mean-annual precipitation is in the range of 83-92 mm, protracted droughts are to be expected and should be considered as normal.

The data in Table 6 were analyzed statistically to determine whether or not the differences in the mean-annual precipitation between stations are significant. Since the data are not normally distributed, the non-parametric Wilcoxon matched-pairs signed-rank test (Siegal, 1956) was used for this purpose.

The results are summarized in contingency table form in Table 7. The numbers given in the body of the table represent the percentage probability that the means for the selected two stations could have come from the same population. The application of the Wilcoxon test may not be completely appropriate here because the paired data were not always for the same time span. From August 1972 through November 1975 the gauges were read about once a month. Before and after that time anywhere from one to six months passed between readings. As long as the time interval between readings is not correlated with the sign and magnitude of the precipitation differences, which seems very likely, there should be little bias in the results.

The statistical analysis indicates that Escondido and Gray Hill are significantly drier and wetter, respectively, than the other four stations. Gray Hill apparently does experience a real increase in rainfall due to its location on the lee side of the Sierra Cirio. The aridity of Escondido is probably also terrain-induced. Apparently even small variations in the topography can produce significant differences in the rainfall regime.

Among the other four stations, Punta Cirio and Coloradito are significantly wetter than Upper or Lower. However, the range of values, 15.82 mm, is probably too small to produce noticeable vegetation differences.

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