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# Analysis Of Rainfall Data From The Island Of Culebra, Puerto Rico Over A Period Spanning 1907-2007 In Light Of Climate Change Predictions

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## ABSTRACT

*Under conditions of human-induced climate change, the Caribbean region is predicted to experience more frequent water shortages. To determine whether rainfall amounts on the island of Culebra have already begun to change, rainfall data spanning 100 years were assessed. Rainfall data had been collected at three different locations during three time periods that did not overlap. There was no evidence of change in annual rainfall amounts or the severity of dry seasons from 1907-2007. It appears that global climate change has not yet affected precipitation on this island, suggesting that current precipitation values represent a baseline that can be used to monitor the hydrologic state of this and climactically similar regions.*

## INTRODUCTION

Culebra's plants, animals, and sometimes people rely to a large extent on surface water. The Intergovernmental Panel on Climate Change has predicted that in the Caribbean, summers will become drier, and that, paradoxically, there will be more winter days with heavy rainfall, so more freshwater will be lost as run-off (Mimura et al. 2007) On small islands such as Culebra, the availability of groundwater is strongly limited and highly dependent upon rainfall events (Anonymous 1998). Moreover, the air temperature in the Caribbean has increased faster than the global average, and will likely result in more rapid evaporation (Mimura et al. 2007).

In order to determine whether rainfall amounts have begun to change as a result of global climate change, rainfall records spanning 100 years were assessed. This investigation was undertaken to determine whether ecological measurements taken early in the current century can be considered to be baseline measurements with regard to rainfall amounts.

## METHODS

*Study location and characteristics*
The study was carried out on the island of Culebra (18.30 N/ 65.28 W), 31 km off the east coast of Puerto Rico, and 19 km east of St. Thomas. Culebra is the

smallest of the inhabited Spanish Virgin Islands, with a total area of approximately 2833 ha, including the neighboring cays. Since the island is small, there is minimal local atmospheric convection, producing a semi-arid climate. Due to a rain shadow, the eastern portion of the island, with cacti growing amongst the trees, tends to be drier than the western portion. Culebra has no permanent lakes or streams, and little to no fresh groundwater. While Culebra had a small number of freshwater wells approximately one hundred years ago (Haeselbarth 1903), the few remaining shallow wells produce water with a high saline content (Bearden 2005). The groundwater levels are solely dependent on rainfall (Anonymous 1996). The depth of the water table beneath hills is estimated to be at least 33 m and in valleys may be less than 3 m (Anonymous 1996).

*Rainfall*

Rainfall accumulation in Culebra from 1907-1975 was recorded at 18.30 N/ 65.28 W and 15 m above mean sea level (amsl) (2008). It is likely that the U.S. Navy recorded these data since they occupied Lower Camp near this location from 1905-1975. Efforts to verify the source of this data through NOAA, the U.S. Navy and the Library of Congress were unsuccessful. Where rainfall amounts were recorded as 'trace' or as estimated to be zero, zero was used. Rainfall data were recorded only irregularly from 1907-1911, 1919-1921 and 1971-75. There were no rainfall data for 1922-1945. Rainfall records were also collected from 1987-1991 in the town of Dewey, at 18.30 N/ 65.31 W and 37 m amsl, and from 1991-2006 at 18.29 N/ 65.29 W at 38 m amsl (Kunke 2007, 2008). During all time periods rainfall data were collected daily, and more frequently during rainstorms. Only monthly records, however, remain for 1987-1999. The weather in Culebra is highly variable by location. Even these collection sites, which are no more than 1.5 km apart, have different microclimates. Therefore, the rainfall records were not compared across locations.

## RESULTS

Twelve-month rainfall totals from Lower Camp for periods beginning in 1907, 1909, 1919, and 1955-1972 averaged 856 mm, and ranged from 362 mm (1967) to 1428 mm (1970). Standard regression analyses predicting 12-mo rainfall totals from the Julian start date for all years and for 1955-1972 only were not statistically significant ($r^2$ = 0.07, df = 20, $P$ = 0.2375; $r^2$ = 0.11, df = 17, $P$ = 0.1836). Dry seasons occurred from December - April and June - July. The total rainfall for the December - April dry season averaged 235 mm, ranged from 85 mm (1967) to 489 mm (1907), and showed no change from 1907-1973, or from 1955-1973 ($r^2$ = 0.05, df = 21, $P$ = 0.3128; $r^2$ = 0.00, df = 18, $P$ = 0.9192). The total rainfall for the June - July dry season averaged 130 mm, ranged from 35 mm (1974) to 262 mm (1968), and showed no change for 1908-1974 or from 1955-1974 ($r^2$ =0.07, df = 23, $P$ = 0.2226; $r^2$ = 0.00, df = 19, $P$ = 0.8532).

Annual rainfall totals from Dewey for 1987-1991 averaged 1160 mm, and ranged from 945 mm (2000) to 1554 mm (1970). Standard regression analyses predicting annual rainfall by year was not statistically significant ($r^2$ = 0.45, df = 4, $P$ = 0.2091). The December

- April time period was dry (188-284 mm). June and July, while not as wet as September, October and November, each averaged over 100 mm of rain.

Annual rainfall totals from the third collection site, near Ensenada Fulladosa, for 1992-2007 averaged 1146 mm, and ranged from 584 mm (2000) to 1722 mm (2003). Standard regression analyses predicting annual rainfall totals by year were not statistically significant ($r^2 = 0.0000$, df = 15, $P = 0.9694$). Dry seasons occurred from December - April and June - August. The total rainfall for the December- April dry season averaged 303 mm, ranged from 124 mm (1993) to 465 mm (2002), and showed no change from 1992-2006 ($r^2 = 0.1020$, df = 14, $P = 0.2459$). The total rainfall for the June-August dry season averaged 241 mm, ranged from 117 mm (1994) to 419 mm (2005), and showed no change from 1992- 2007 ($r^2 = 0.02$, df = 15, $P = 0.5826$).

## DISCUSSION

Ecological data that are collected prior to environmental change are valuable as they provide a baseline for future comparisons. Rainfall data from Culebra showed differences between collection locations/time periods, with the greatest annual rainfall amounts in the town of Dewey (1987-1991), and much less at Lower Camp (1907-1975). The Ensenada Fulladosa site had the longest summer dry season, while the summer dry season in Dewey, in a different set of years, was barely notable. These differences are reflected in the distribution of plant functional types on the island (Woodbury 1984) suggesting that location has had a stronger influence on rainfall amounts than has time period.

In none of the three collection locations/time periods was there a trend toward a wetter or a drier climate, and no change in the severity of dry seasons. These results suggest that the predicted increase in water stress due to human-induced climate disruption (Mimura et al. 2007) has not yet begun in this region. Therefore, the information presented here can be legitimately assumed to provide a baseline for comparison with future studies that may identify climatically-induced change. The apparent decrease in fresh groundwater availability may be due to increased run-off due to deforestation and paving. Future rainfall measurements should be taken, if possible, at the Lower Camp location because this location provides the earliest and longest record, and thus would provide the most useful location for comparisons.

## ACKNOWLEDGEMENTS

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