

# Ambient temperature increase and its possible association with suicide in the Population of Baja California Sur (BCS) 1985-2008

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Original article

## SUMMARY

### Introduction

During the last decade we have observed important climate changes, especially in ambient temperatures. There is considerable information linking the increase in hot weather to human health. For example, hot weather is associated with an increased risk of suicide in different countries around the world.

### Objective

To evaluate the relationship between suicide rates and the environmental temperature in Baja California Sur, Mexico from 1985 through 2008.

### Method

Suicide mortality data for Baja California Sur (BCS) was obtained for the years 1985-2008 from the Instituto Nacional de Estadística, Geografía e Informática (INEGI). The selected codes were: E950-E959 (ICD-9) and X60-X84, Y87.0 (ICD-10) for BCS. The BCS weather data used was the maximum temperature from 1985 to 2008, obtained from the Extractor Rápido de Información Climatológica [ERIC III]. Lineal and quadratic models were used to assess the annual rate changes of suicide and generalized lineal models (GLM) to assess the effect of the climatological variables to the suicide rate. The  $p \leq 0.05$  was considered significant.

### Results

In BCS, 582 suicide deaths were reported from 1985 through 2008. Some 9% (53) of the total reported were women with a yearly average rate of 1.6/100,000; 91% (529) were men with a yearly average rate of 16.3/100,000. Lineal and quadratic models explained the tendency of the annual increment observed in the number of suicides in both seasons. The quadratic model better explained this increment during the warmer months ( $R^2=0.64$   $p < 0.01$ ). The temperature was positively correlated with the rate of suicides in both seasons ( $p < 0.01$ ). Two predictive GLMs were created by season.

### Discussion

These results suggest a potential link between an increase in ambient temperature and the rates of suicide during 24 years in BCS. This relationship is clear during the hot season; however, a positive trend was also found during the cold season, perhaps due to the result of warmer winters.

**Key words:** Climate changes, suicide, Baja California Sur.

## RESUMEN

### Introducción

Durante las últimas décadas se ha podido apreciar un cambio en las variables climáticas, en especial en la temperatura ambiental. Hay evidencias que asocian el aumento de la temperatura ambiental con el incremento en las tasas de mortalidad por suicidio.

### Objetivo

Evaluar la relación entre la tasa de suicidio y la temperatura ambiental en Baja California Sur (BCS) durante los años 1985-2008.

### Método

Los datos de suicidio fueron obtenidos de las bases de Mortalidad del INEGI de 1985-2008. Se tabularon los registros con códigos: E950-E959 CIE-9 y X60-X84, Y87.0 CIE-10 para BCS. En el análisis climático se usaron las temperaturas máximas de 1985 al 2008 para BCS del Extractor Rápido de Información Climatológica (ERIC III). Para evaluar la tendencia, se utilizaron modelos de regresión lineal y cuadráticos. Los modelos lineales generalizados (GLM) se utilizaron para evaluar el efecto de las variables ambientales sobre la tasa de suicidios, con una significancia de  $p \leq 0.05$ .

### Resultados

Un total de 582 suicidios ocurrieron en BCS de 1985 a 2008. Las mujeres representaron el 9% (53), con tasa anual promedio de 1.6/100 000. Los hombres 91% (529), con tasa promedio anual de 16.3/100 000. La tendencia de incremento anual se explicó con modelos lineales simples y cuadráticos en ambas temporadas. En los meses cálidos el modelo cuadrático explicó mejor dicho incremento ( $R^2=0.64$   $p < 0.01$ ). La temperatura se correlacionó positivamente con la tasa en ambas temporadas ( $p < 0.01$ ). Se generaron dos modelos GLM predictivos por temporada.

### Discusión

En este trabajo se observó una posible relación entre el incremento de la temperatura ambiental y el número de suicidios registrados durante 24 años en BCS. Esta relación se encuentra bien definida en los meses cálidos, pero con una tendencia en aumento para los meses fríos.

**Palabras clave:** Cambio climático, suicidio, Baja California Sur.

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## INTRODUCTION

The idea of relating aspects of climatology with human health is as old as humanity itself. Some 2,400 years ago, Hippocrates referred to meteorological variations and health. He wrote in his work *On airs, waters, and places*: "whoever wishes to investigate medicine properly, should proceed thus: in the first place to consider the seasons of the year, and what effects each of them produces....Then the winds, the hot and the cold..."<sup>1</sup>

To date, there have been many works that have attempted to relate human health with climatic factors, especially in regard to how these affect morbidity and mortality.<sup>2,3</sup> The epidemiological evidence demonstrates that an increase in environmental temperature causes thermic stress, an increase in infectious diseases, destruction of crops, death of livestock, and consequently famine.<sup>4</sup>

Heat affects individuals with limited adaptive responses; among these vulnerable groups are the elderly and those with chronic illnesses.<sup>5</sup> A study was conducted in Italy between 1974 and 2003 in which global warming was associated with an increased risk of suicide.<sup>5</sup> The presence of heat waves was also associated with an increase in the number of suicides in the population of the United Kingdom.<sup>6</sup> However, these are both countries with temperate climates, which begs the question of what happens in tropical places or countries that are truly hot.<sup>7</sup>

Suicide in Baja California Sur (BCS) has been approached from the national context, which sees it fall within the top five places.<sup>8</sup> Despite the magnitude of this for the state, this will only be the second work to tackle the problem from an epidemiological point of view. In the previous work, it was reported that males ended their lives at a higher rate than females. Marriage in age groups under 43 years had a reductive effect on the risk, but after 44 years of age, married individuals were more vulnerable. In terms of population size, communities with fewer than 20,000 inhabitants presented a higher risk.<sup>9</sup>

BCS is a federal entity of the Mexican Republic with a hot and arid climate.<sup>10</sup> The region is influenced by various meteorological factors and global warming has been in evidence in recent decades.<sup>11</sup> There has been a 0.74°C increase in the ambient temperature and it is rising rapidly. In a state where the limitation of water resources has been crucial to its development, an increase in the duration and intensity of droughts is causing death to livestock and forest fauna, as well as a decrease in water supply and dysfunction in crop areas.<sup>11</sup>

Because of the above, the aim of this work is to assess the relationship between the suicide rate and the ambient temperature in BCS during the years 1985-2008.

## METHOD

In order to carry out this work, an ecological section study was carried out. This type of study works with the exposure

level of various groups of individuals (or the same group at different periods of time), and the information is aggregated in databases at geographical unit level.<sup>12</sup> For the present study, data on suicide was obtained from the mortality bases of the Instituto Nacional de Estadística, Geografía e Informática (INEGI) [in English; National Institute for Statistics, Geography, and Computing] from the years 1985 through 2008.<sup>13</sup> Only records corresponding to BCS and those over 14 years of age were tabulated from national level mortality records, according to the codes E950-E959 of the 9<sup>th</sup> revision of the International Classification of Diseases (ICD-9)<sup>14</sup> and X60-X84, Y87.0 from the 10<sup>th</sup> revision (ICD-10).<sup>15</sup> The selection of subjects over 14 years of age was due to suicide rates becoming consistent in late adolescence in males and half of that in females.<sup>16,17</sup> The variables considered in cases of death were age, sex, and where the event took place.

Data on maximum daily temperature for BCS between 1985 and 2008 was used in order to create the climatic variable. The information was extracted from the Extractor Rápido de Información Climatológica (ERIC III) database [Rapid Extractor of Climatological Information in English], created by the Instituto Mexicano de Tecnología del Agua [Mexican Institute of Water Technology]. These records were updated with the data from the Servicio Meteorológico Nacional [National Meteorological Service].<sup>18</sup> The study was delimited at 24 hours because the database information about suicides dated prior to 1985 only gave the year of the event, not the month, meaning the period of the year could not be established. Suicide mortality rates were calculated as the total number of deaths due to suicide in a given period, divided by the number of persons within that period (year). The rate denominator projected linearly<sup>19</sup> from the population registered in the general population censuses from 1980,<sup>20</sup> 1990,<sup>21</sup> and 2000,<sup>22</sup> and in the overall population counts from 1995<sup>23</sup> and 2005.<sup>24</sup> The maximum daily temperature was averaged out by month and by season for each year as follows: hot temperatures from May through October and cold temperatures from November through April. Hot months were calculated as those which had an average temperature over 30°C.<sup>11</sup>

In order to assess changes in the suicide rate over time, a trend study was used. Suicide rates were grouped according to seasons (hot or cold) and by sex. Prior to the statistical analyses, an assessment was made of assumed normality. Student's *t* analysis and ANOVA were both used to assess differences in the suicide rate between age, season, and year, and Tukey's test was used as an *a posteriori* test to carry out the various comparisons. In order to assess the increase trends in the rate of suicide, temperature, and relationships between both variables, lineal regression models and quadratic regression models were used with a significant value of  $p \leq 0.05$ .<sup>5</sup> The quadratic model assumes the possibility that the suicide rates change over the years and that the trends for that variable will be projected in a parabola in place of a lin-

**RESULTS**

real trend. This model could explain the changes by which an increase could be followed by a decrease in the suicide rate.<sup>5</sup>

With the aim of assessing the effect of environmental variables (temperature and season) on the suicide rates recorded in BCS, and at the same time, predict the incidence of suicides in terms of those variables, a generalized lineal model (GLM) was generated with a Poisson distribution error and a logarithmic link function.<sup>25</sup> The log link function ensures that all the values that could take the dependent variable (suicide rates) are positive, while the Poisson error takes into account the fact that the data is made up of whole numbers and that the variances are equal to their halves.<sup>26</sup> A mixed generalized model, a particular case of GLMs, was created in order to assess the contribution of the random effect of the categorical variable of "year" on the predictions.<sup>26</sup>

All possible models were generated, starting from a maximum model which included all variables and interactions of interest (temperature\*season). The quadratic term of the variable "temperature" was also included in the analysis to assess its significance in the fit of the model.

The best model was selected by means of a comparison of the residual *deviance*, a measure of discrepancy of the fit of the model,<sup>27</sup> following the parsimony principle.<sup>26</sup> Once the model had been selected, a residual analysis was made in order to investigate the fit capacity of the same in relation to the data observed.<sup>26</sup> The statistical packages used were FOXPRO, Excel 2007, SPSS V13.0, Statistica v.7, and R v.2.14.0.

A total of 582 suicides occurred in BCS from 1985 through 2008. Women represented 9% (n=53, annual average 2) of total suicides, with an average annual rate of 1.6 for every 100,000 women (range: 0 to 4.08). Some 91% of cases (n=529; annual average 22) were suicides carried out by men, with an annual average of 16.3 for every 100,000 men (range: 4.58 to 24.17) (Table 1). Women were younger, with an average age of 29.1 years (standard deviation; SD= 13.3) than men, the average age of whom at the time of the event was 37.3 years (SD= 17.1) ( $F_{(1,11)}=12.00$ ;  $p<0.01$ ).

The suicide rate was significantly higher during the hot weather in comparison to the cold ( $t_{(105,2),46}=-2.55$ ,  $p<0.01$ ) (figure 1a). During the 24 years analyzed in the present study, an ascending trend was found in the suicide rate, both in the cold months as well as the hot ones ( $F_{(23,24)}=2.22$ ,  $p=0.02$ ) (Figure 1a). There were annual variations in the incidence of suicides, and a significant increase was observed after 1996. The suicides recorded from 1985 through 1988 were significantly fewer in comparison to the period 1996 through 2007 (Tukey,  $p<0.05$ ) (Figure 1a).

The increasing trend in the number of suicides over the years during the hot seasons is explained with a lineal model ( $R^2=0.58$ ,  $p<0.01$ ;  $F_{(1,22)}=33.2$ ). However, fitting the data by means of a quadratic regression ( $R^2=0.64$ ,  $p<0.01$ ) was the model that better explained the phenomenon in that season.

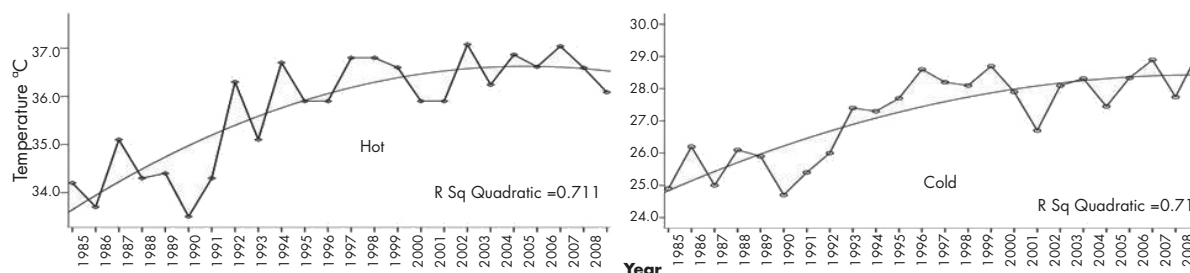
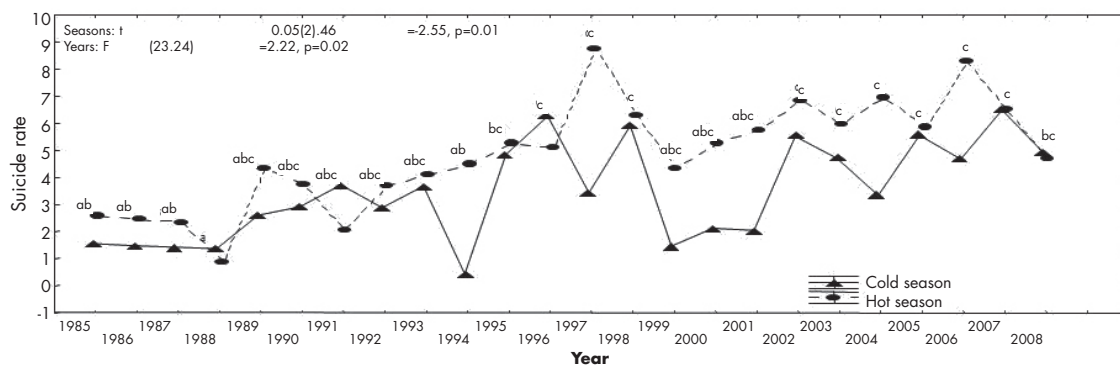
**Table 1.** Description of suicide mortality in Baja California Sur and maximum temperatures averages according to warm season (May to October), cold season (November to April). 1985 to 2008.

Year	Population*	Suicides (n)				Suicide rate**				MTA***	
		M	W	C	H	M	W	C	H	C	H
1985	195919	8	0	3	5	8.33	0.00	1.53	2.55	24.9	34.2
1986	204901	7	1	3	5	6.97	0.96	1.46	2.44	26.2	33.7
1987	213883	6	2	3	5	5.73	1.83	1.40	2.34	25.0	35.1
1988	222864	5	0	3	2	4.58	0.00	1.35	0.90	26.1	34.3
1989	231846	14	2	6	10	12.32	1.69	2.59	4.31	25.9	34.4
1990	240828	16	0	7	9	13.56	0.00	2.91	3.74	24.7	33.5
1991	242156	12	2	9	5	10.11	1.62	3.72	2.06	25.4	34.3
1992	243483	15	1	7	9	12.57	0.81	2.87	3.70	26.0	36.3
1993	244811	17	2	9	10	14.17	1.60	3.68	4.08	27.4	35.1
1994	246138	11	1	1	11	9.12	0.80	0.41	4.47	27.3	36.7
1995	247466	22	3	12	13	18.14	2.38	4.85	5.25	27.7	35.9
1996	254970	28	1	16	13	22.41	0.77	6.28	5.10	28.6	35.9
1997	262473	30	2	9	23	23.33	1.49	3.43	8.76	28.2	36.8
1998	269977	30	3	16	17	22.68	2.18	5.93	6.30	28.1	36.8
1999	277480	16	0	4	12	11.77	0.00	1.44	4.32	28.7	36.6
2000	284984	20	1	6	15	14.32	0.69	2.11	5.26	27.9	35.9
2001	296307	21	2	6	17	14.46	1.32	2.02	5.74	26.7	35.9
2002	307629	34	4	17	21	22.56	2.55	5.53	6.83	28.1	37.1
2003	318952	31	3	15	19	19.84	1.84	4.70	5.96	28.3	36.2
2004	330274	30	4	11	23	18.54	2.37	3.33	6.96	27.4	36.9
2005	341597	36	3	19	20	21.51	1.72	5.56	5.85	28.3	36.6
2006	363109	43	4	17	30	24.17	2.16	4.68	8.26	28.9	37.0
2007	384622	42	8	25	25	22.29	4.08	6.50	6.50	27.7	36.6
2008	406134	35	4	20	19	17.59	1.93	4.92	4.68	29.1	36.1

M = Men; W = Women; MTA = Maximum Temperatures Averages; C = Cold months; H = Hot months.

\* Population older than 14 years; \*\* Suicide rate per 100,000 inhabitants; \*\*\* Temperature expressed in degrees celsius.

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**Figure 1. a)** Suicide rate by hot season (May - October) and cold season (November - April) by year in Baja California Sur. The different letters above the scores denote significant differences between the years. **b)** Trends in temperatures by hot season (May - October) and cold season (November - April) in Baja California Sur from 1985 through 2008.

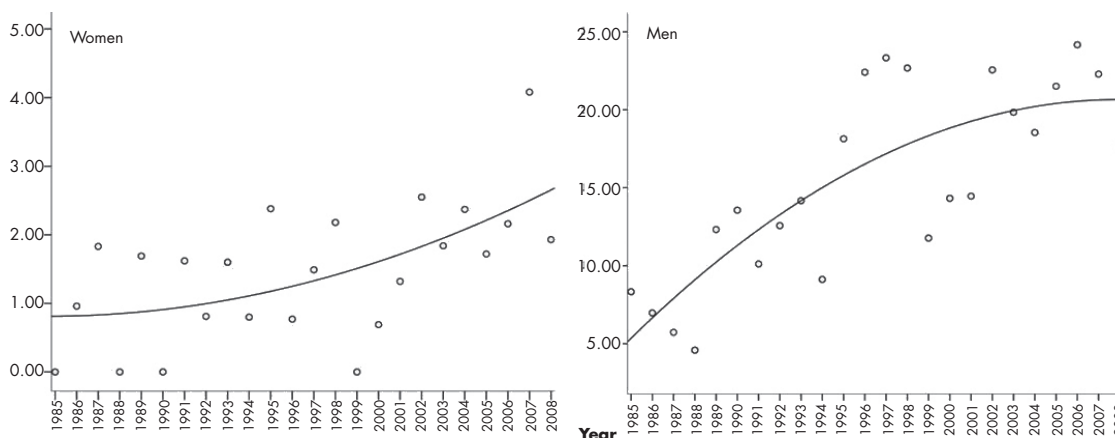
In the cold season, the increasing trend was also statistically significant and was observed by means of a simple lineal regression ( $R^2=0.38$   $p<0.01$   $F_{(1,22)}=13.3$ ). In this season, the quadratic model did not significantly contribute to the fitting of the data in comparison to the lineal model ( $R^2=0.38$ ,  $p<0.01$ ).

The increasing trend was analyzed for the suicide rate over the years taking sex into account (figure 2). In the case of females, the quadratic model ( $R^2=0.35$   $p<0.01$ ) better explained the phenomenon in 6% in comparison with the lineal model ( $R^2=0.33$ ,  $p<0.01$   $F_{(1,22)}=6.7$ ). In males, the quadratic model ( $R^2=0.64$ ,  $p<0.01$ ) improved the fit by 8% in

comparison with the simple lineal model ( $R^2=0.59$   $p<0.01$ ,  $F_{(1,21)}=33.2$ ).

When analyzing the climatic data, an ascent was found in the temperature of both seasons over the years, with an increase of 71% for both seasons (quadratic model  $R^2=0.71$   $p<0.01$ ) (figure 1b). A statistically significant positive correlation was found between temperature and suicide rates and both seasons (hot:  $R^2=0.68$   $p<0.01$ ,  $F_{(2,21)}=22.3$ ; cold:  $R^2=0.033$   $p<0.01$ ,  $F_{(2,21)}=5.1$ ).

The random effect of the year and the quadratic term were not factors that significantly contributed in predicting the suicide rate in the GLMs. The minimum fitted model was



**Figure 2.** Trends in suicide rate by sex in Baja California Sur from 1985 through 2008. The Y axis shows the suicide rate per 100,000 inhabitants; the X axis shows years.

that which included the ambient temperature and seasonal variables, which were significantly related to the suicide rate. Predictive models for the suicide rate were produced from these results explained by the temperature variable for each of the seasons:

$$R. \textit{suicides cold} = e^{-6.40 + 0.28\textit{Temperatura}} \quad [1]$$

$$R. \textit{suicides hot} = e^{-8.42 + 0.28\textit{Temperatura}} \quad [2]$$

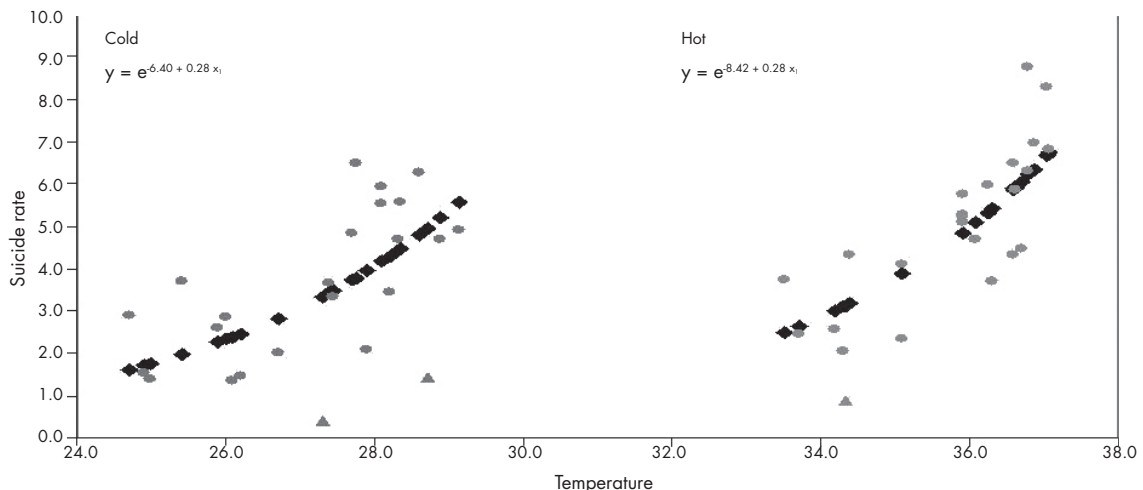
Where model 1 predicts the suicide rate in BCS during the cold months (November through April), model 2 generates predictions during the hot months (May through October) (figure 3). During the residual analysis, it was identified that the proposed models do not adequately predict the suicide rate when it has values close to zero (figure 3).

### DISCUSSION

This exploratory study suggests a relationship between the increase in ambient temperature and the number of recorded suicides in BCS, Mexico over 24 years. This relationship is well defined in the hot months, but with an increasing trend in the cold months, a result of warmer winters and the raised temperature during this period. This climatic change has already been reported by Gutiérrez-Ruacho.<sup>11</sup> At an international level, there is evidence of climatic change and its relation to suicide. In Europe, winters have become less cold with an increase in suicide during this period.<sup>5,28</sup> Furthermore, suicide is a more common event among males. Part of this phenomenon could be attributable to the possible action of risk reduction conferred by steroid hormones in females. In the case of males, it is possible that androgens participate in impulsive behavior that characterizes the act of suicide, or even that the lack of the possible protective action of progesterone and estradiol may contribute.<sup>29</sup> Many

other explanations have been proposed, given that the pattern of suicide in males during the hot months has been widely reported.<sup>6,30-33</sup> Within these possible explanations, the most plausible for BCS is the action of heat on the ways that make up perception of the environment; information that is controlled in circuits of emotional memory, which pass over into decision making. The functional alterations of this circuit, together with adverse environmental factors such as heat, seem to provoke the act of suicide. One of the primary clinical entities related to suicide is depression, but it is not the only one. Bipolar disorder and schizoaffective disorder are also risk factors. Any of the above, combined with the agitation and impulsivity caused by thermic stress, can provoke suicide.<sup>29,34</sup>

Preti (2007) related suicide in Italy with global warming,<sup>5</sup> commenting that there is an inability in some sections of society to respond to climatic change, especially among males, and that this can furthermore increase with age. In a previous work in 2009 related to suicide in the BCS population, an increase in suicide risk was reported in males, which may be explained by Preti's comments about the inability to react to the stress and discomfort caused by the heat.<sup>5,9</sup> This is observed not only during the summer but the cold season too, which is becoming hotter, and which is expressed in an increase of suicide in this section of BCS society. The trend of suicide in males between 1985 and 1997 was ascending, and from 1998 through 2008, a reduction was seen in the previous 11 years. In contrast, in the previous 11 years, an increase in the suicide trend among females has been observed. Similar reports have been presented in Slovenia and Italy.<sup>35,36</sup> Commentaries have been directed towards an increase in suicides among women during the months of January through June, in comparison to the period July through December. This seasonal pattern conforms more with episodes characterized by changes in mood than by mental disorders.<sup>36</sup>



**Figure 3.** Suicide rate in relation to temperature by hot season (May - October) and cold season (November - April) in Baja California Sur. (◆) Model predictions; (●) data observed; (▲) data not fitted by the model.

It is not possible to establish a one-directional association between suicide and heat; multiple factors are involved in this phenomenon. In BCS society, the lack of social cohesion and the protection that provides is one of the factors that make individuals, males in particular, more susceptible to suicide.<sup>9</sup> Another situation is the increase in health problems such as different types of cancer and chronic illnesses that could also precipitate suicide.<sup>37</sup>

The current work replicated a statistical analysis used by Preti's team, and consistency was found in the method. The original contribution of the present study is the use of GLMs as a statistical tool. These models are a good option as they help to eliminate the effects of co-linearity in highly-correlated series and with those, estimate in the same equation the effect of the statement.<sup>38</sup> A predictive model for suicide rates was integrated with this in relation to the ambient temperature for each season. The limitations around this method are typical of ecological studies which establish the correlation at a group level and not an individual level, and the reduced number of variables that are used for its analysis.<sup>12</sup> Another situation that limits the present study is establishing a relationship between the average monthly temperatures and later by season and suicide event, which is also grouped monthly and by season. Due to the limited number of observations, it is not possible to do this in any other way. Despite the biases of this information, it is possible to establish a relationship between the increase in ambient temperature and climate change that has been experienced over recent years, and suicide.

## CONCLUSION

The climate change and its potential health effects experienced by the BCS peninsula are evident. The present work demonstrates the possible relationship between suicides and the increase in ambient temperature. The two predictive models generated showed how the ambient temperature allows an identification of the trend in the rate of suicides for both seasons. With this type of analysis, it is possible to compare whether the same pattern exists with respect to suicide and the ambient temperature in other regions of Mexico with a high risk of suicide, that share with BCS the common factor of high ambient temperatures.

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