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Descriptive Finding

The vanishing advantage of longevity in Nicoya, Costa Rica: A cohort shift

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The vanishing advantage of longevity in Nicoya, Costa Rica: A cohort shift

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Abstract

BACKGROUND
The Nicoya region in Costa Rica has been identified as one of a handful of hotspots of extreme longevity. The evidence supporting this status comes mostly from observing the 1990 and 2000 decades and cohorts born before 1930.

OBJECTIVE
To determine how the longevity advantage of older men in Nicoya has progressed in the period 1990 to 2020 and in cohorts born from 1900 to 1950.

METHODS
Remaining length of life and adult mortality were estimated using new public administrative records from the electoral system and a Gompertz regression model. A new nationwide survival-time database of 550,000 adult Costa Ricans who were alive at any point during 1990–2020 was put together.

RESULTS
The longevity advantage of Nicoya is disappearing in a trend driven mostly by cohort effects. While Nicoyan males born in 1905 had 33% lower adult mortality rates than other Costa Ricans, those born in 1945 had 10% *higher* rates. The original geographic hotspot of low elderly mortality, coined the Nicoya blue zone, has decreased to a small area south of the peninsula around the corridor from Hojancha inland to the beach town of Sámara. However, Nicoyans born before 1930 who are still alive continue to show exceptionally high longevity.

CONCLUSIONS
Surviving Nicoyan males born before 1930 are exceptional human beings living longer than expected lives. Not so for more recent cohorts. The window of opportunity to meet and study pre-1930 individuals is closing.

CONTRIBUTION
Hotspots of extreme longevity are probably transient, and their status should be reassessed continuously.

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1. Introduction

Nicoya – a northwestern region of Costa Rica with 207,000 inhabitants[2] – is considered one of a handful of global "blue zones," a label coined to designate hotspots of extraordinarily high longevity (Buettner 2010; Poulain et al. 2021; Poulain, Herm, and Pes 2013).

The evidence supporting this blue zone status comes mostly from adult mortality data covering the decades of 1990 and 2000 on cohorts born before 1930. The median remaining life span at age 60 in Nicoyan males (24.3 years) was 2.7 years longer than in contemporaneous Japan, the country with the highest life expectancy in the world, and 3.1 years longer than in all of Costa Rica (Rosero-Bixby, Dow, and Rehkopf 2013). Nicoyan females did not show exceptionally high longevity.

This descriptive article aims to determine how the longevity advantage of older men in Nicoya has progressed in the period 1990 to 2020 and in cohorts born from 1900 to 1950. It uses newly available administrative data.

The identification of hotspots of human longevity, as well as their persistence over time, is of great scientific – and popular – interest in the quest for information about successful aging and extended longevity (Wilcox et al. 2008). The extreme longevity of people in Nicoya has the added value of occurring under adverse circumstances of low economic, social, and infrastructure development (Rosero-Bixby, Dow, and Rehkopf 2013), suggesting that sophisticated medical facilities and high living standards may not be necessary conditions for high longevity.

2. Data and methods

This research used public micro-databases of deaths, births, and voters provided by Costa Rica's Supreme Electoral Court (Tribunal Supremo de Elecciones, or TSE), which oversees civil registration. Mimicking procedures used in the analysis of quasi-extinct cohorts (Vincent 1951), this study put together a survival-time national database with the following inclusion criteria: born in Costa Rica between 1900 and 1950[3] and having a death record in the period 1989–2020 or appearing in at least two electoral rolls of the nine presidential elections conducted from 1990 to 2022. The records of these individuals were linked to the birth registry database to obtain their exact dates of birth and thus their

[2] The original Nicoya blue zone encompasses the cantons of Santa Cruz, Carrillo, Nicoya, Nandayure, and Hojancha in the northern part of the Nicoya Peninsula. The population figure is from the 2022 census.

[3] Cohorts born before 1900 were excluded because the sample size was too small (N = 3,612) and individuals with late registration were too many (10%). Cohorts born in 1950 or later were excluded because they were too young during the study period.

exact ages at any point in time.[4] All Costa Ricans receive a unique identification number (*cédula*) at birth, allowing these linkages in a precise way. Evaluations of coverage of Costa Rican death and birth registries in recent decades have concluded that they are complete (Glei, Barbieri, and Santamaría-Ulloa 2019; Pérez-Brignoli and López-Ruiz 2017), which means that this study is not biased by excluding some groups of Costa Ricans (nonregistered births) and is not underestimating mortality by leaving out nonregistered deaths.

The survival-time database included, in rounded numbers, 550,000 individuals, with 285,000 of them (52%) being deceased and 10,000 (2%) considered lost to follow-up because they disappeared[5] from the voting rolls (probably due to outmigration). These figures exclude 20,000 naturalized individuals as well as 28,000 individuals whose birth was registered late in life. These exclusions minimize the possibility of error in the date of birth and therefore in age, which is important since age error is a pervasive problem when studying very old individuals, who are prone to age exaggeration when age is self-reported.

The community of residence of each individual was set as the polling place (*distrito electoral*) where the individual was registered to vote. There were 2,026 polling places in the database (TSE 2021). For spatial analysis purposes, the geographic coordinates for each voting place were obtained from Google Maps and from maps used by the TSE. Individuals are considered Nicoyan if they are registered to vote in one of the five cantons of the Nicoya region. (Note that this is a time-varying attribute.)

To contextualize the results, comparative estimates for Japan, the country with the highest life expectancy in the world, were obtained from the Human Mortality Database (HMD) (HMD 2022).

The article includes three complementary analyses of adult mortality in Costa Rica, with the attribute "living in the Nicoya region" as the factor variable of interest:

1. Estimates of the expected remaining life among adults in Nicoya and Costa Rica (and Japan as a benchmark) by period and cohort decades were calculated. The metric of choice to represent longevity after age 60 was the median remaining years of life (ML) – the time when a cohort of 60 years old reached 50%

[4] The survival-time dataset was created with the date of entry into observation at either the birthday in 1989 if the individual was born before 1930 or the 60th birthday if the individual was born in 1930 or later. The observation exit time was the date of death, the birthday in 2020 for survivors, or an imputed date of loss to follow-up for the 2% who disappeared from the voting rolls. There were 8.7 million person-year observations, 5% from Nicoya. The observation period for each individual was split into one-year age segments in order to conduct the analyses as discrete time events.

[5] The TSE excludes from the electoral roll individuals who fail to renew their *cédula*, which has a validity period of ten years.

mortality.[6] The estimate assumed that the age-specific death rates followed a Gompertz function after age 60 (rationale and details in Rosero-Bixby, Dow, and Rehkopf 2013). The two Gompertz parameters – the intercept alpha and the gamma rate of increase in the death risk with age – were estimated with Poisson regression (Statacorp 2020). The following identity defines ML:

$$ML = (1/\gamma) \cdot ln[1 + (\gamma/\alpha) \cdot ln(2)]$$

2. Age, cohort, and period (ACP) effects were visualized and parsed by plotting the relative mortality rate (RMR) in Nicoya compared to Costa Rica on a Lexis surface (Caselli, Vaupel, and Yashin 1985) and by estimating an ACP model following the method proposed by Agnus Deaton (Deaton 1997) using Poisson regression (Statacorp 2020):

$$RMR = constant \cdot \alpha_A \cdot \beta_C \cdot \gamma_P \cdot error,$$

   where alpha, beta, and gamma are vectors for the estimated ACP effects – i.e., the regression coefficients of sets of dummy variables for every single year of age A, cohort C, and period P, respectively.
3. Spatial analysis using the SatScan procedure (Kulldorff 1997) was performed to determine whether Nicoya continued to be a dominant Costa Rican hotspot of low adult mortality in the 2010 decade, replicating the analysis conducted in the study that discovered the Nicoya blue zone (Rosero-Bixby, Dow, and Rehkopf 2013). The spatial analysis was conducted using age- and sex-adjusted death rates in the 2010 decade in people aged 65 and older residing in 2,026 Costa Rican locations.

The Stata program for Analyses (1) and (2), aggregated data files used, and details about SatScan are included as supplemental material.

[6] ML is an indicator of a magnitude similar to the life expectancy concept. ML is the median, while life expectancy is the mean of death distribution. ML can be easily computed with a Gompertz model and is not confounded by the right truncation of non-extinct cohorts.

3. Results

The estimated ML at age 60 was 24.0 years in Nicoyan males in the 1990 decade.[7] This was an exceptionally high ML for that period: almost four years higher than those in Costa Rica and Japan (Figure 1a). However, while ML improved over time in the other populations, the ML in Nicoyan males did not change, and in the 2010s, the ML in Japanese males (24.5 years) surpassed that in Nicoyan males, which became similar to the national Costa Rican ML (23.6 years). The longevity advantage in Nicoyan males essentially vanished according to period mortality estimates for the 2010 decade.

The ML estimates by cohort (Figure 1b) showed that Nicoyan men born between 1900 and 1929 lived, or are living, markedly longer than Japanese and other Costa Rican males. In particular, Nicoyan men born in the 1900 to 1910 decade had a notable ML of 26.2 years, 8.5 years longer than Japanese men and 6.6 years longer than Costa Rican men. This longevity advantage of Nicoya diminished over cohort decades. ML was similar to that in Japan in the 1930s cohorts, while in the 1940s cohorts, ML in Nicoyan men was 1.4 years shorter than in Japan.

Regarding women, Nicoya had a lower ML than Japan in all periods and cohorts, except the cohort born in the 1900 to 1910 decade. Therefore women in Nicoya do not seem to have exceptionally high longevity. However, women in Nicoya showed a slight advantage in longevity over other women in Costa Rica in both the period and cohort analyses.

A problem with the period and cohort estimates presented thus far is that they are mutually confounded. To better visualize them, Figure 2 shows the Lexis surfaces of the RMR in Nicoya compared to that in Costa Rica. Cells with a substantially lower Nicoya death rate (RMR < 0.80) are colored blue.

Blue cells tend to disappear toward the right-hand side of the Lexis surfaces (period effect), especially diagonally toward the lower right corner (cohort effect). An age effect is also distinguishable: Blue cells within the same cohort seem to be less frequent at older ages.

Figure 3 shows the results obtained from the regression procedure proposed by Deaton (1997) to disentangle ACP effects on the RMR observed in the Lexis surface. The plots show marginal effects – i.e., those that take place at mean values of the other two variables in the model. The points show the results obtained from the regression models. Lines in the plots estimate time trends by fitting the corresponding points with local regression. Lower RMR figures indicate a greater advantage of longevity in Nicoya.

[7] The study by Rosero-Bixby, Dow, and Rehkopf (2013) estimated the ML-60 of Nicoyan males at 24.3 years (95% C.I.: 23.0–25.8) by following up a sample of 450 individuals during the period 1990–2010. Table S1 shows the numerical results, including the Gompertz parameters.

Figure 1: Median remaining years of life (ML) at age 60 by sex, period, and cohort, comparisons of Nicoya to Costa Rica and Japan

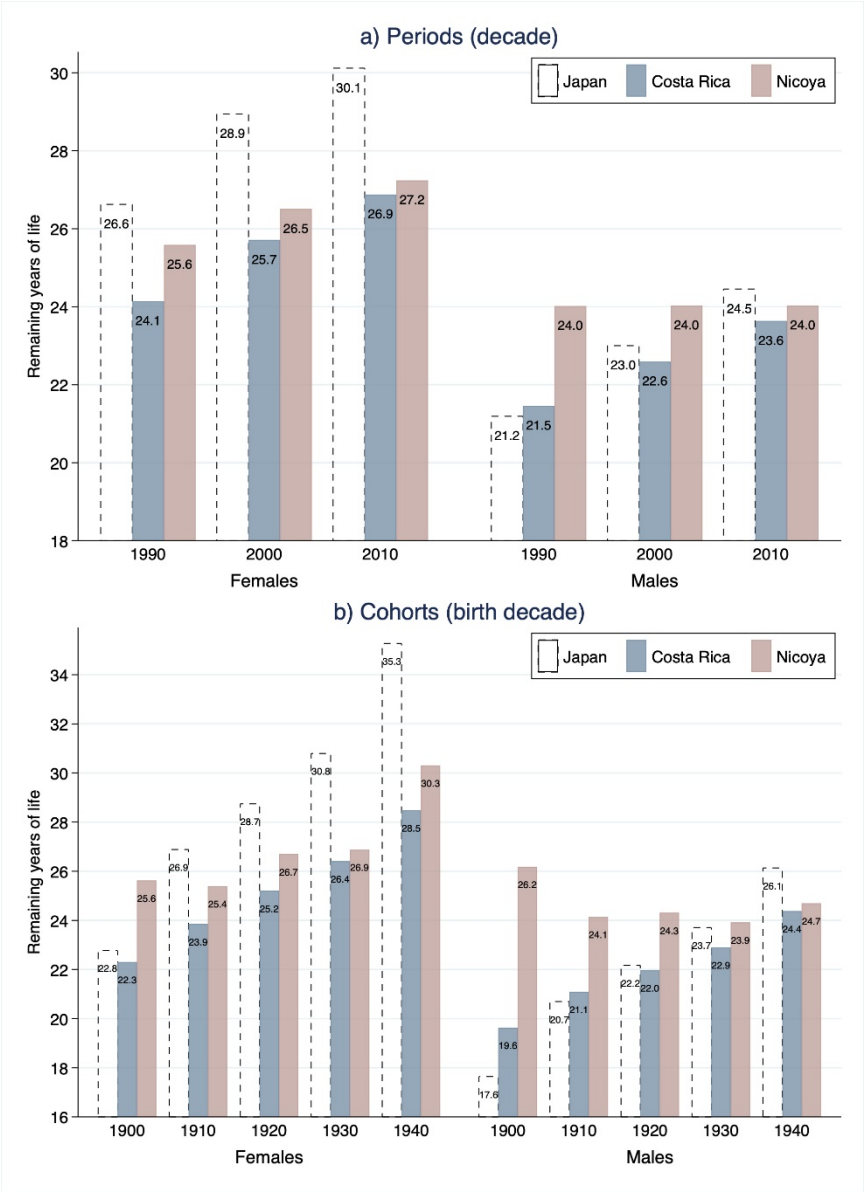
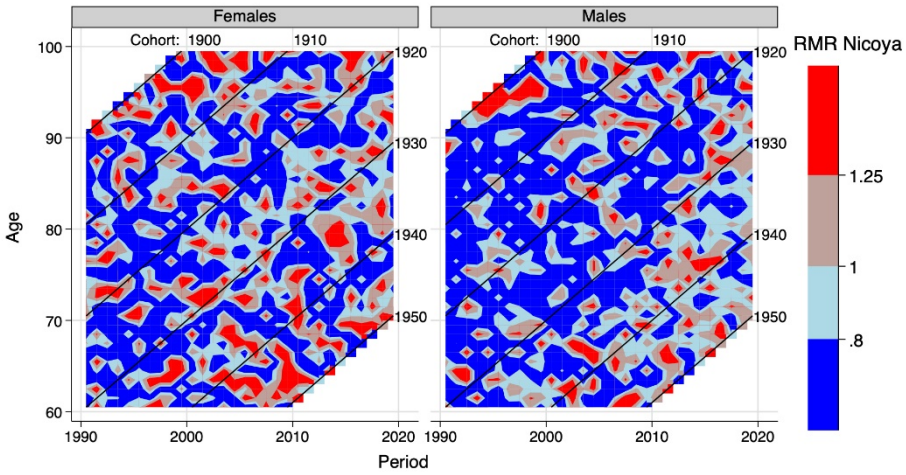


Figure 2: Lexis surfaces of the relative mortality rate (RMR) in Nicoya compared to that in Costa Rica by sex. Native-born Costa Ricans aged 60 years and above. Diagonal lines indicate cohorts



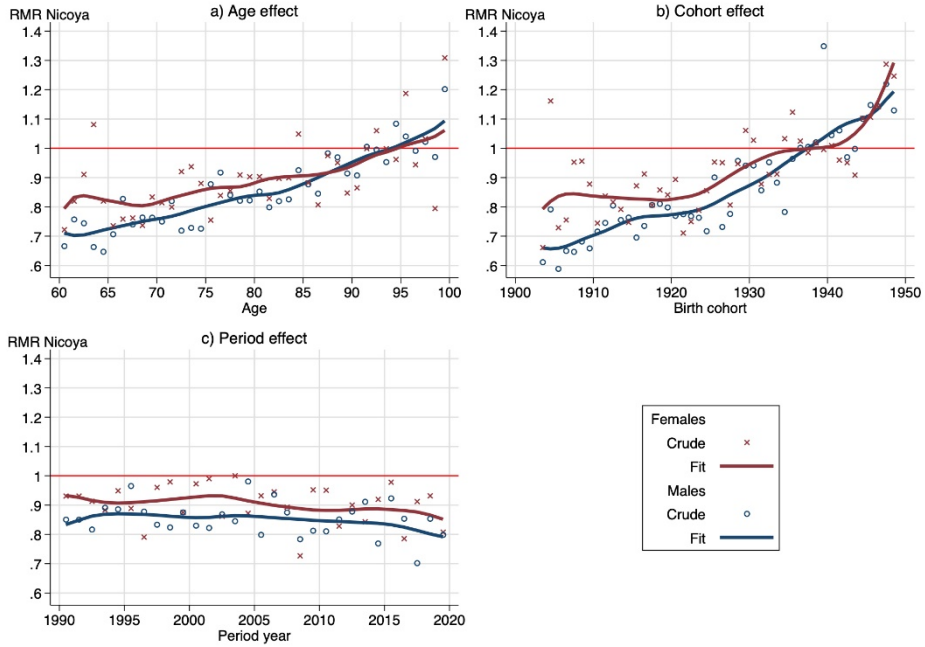
The lower blue lines for males confirm that the Nicoya longevity advantage tends to be greater among males than among females.

The estimated age effects (Figure 3a) suggest that the Nicoya longevity advantage was attributable to mostly lower death rates in middle adulthood. For example, compared to the average among Costa Ricans, Nicoyan males aged 60 had an approximately 30% lower death risk, while those aged 95 had approximately the same death risk as other Costa Ricans.

The rising cohort-effect curves approaching or surpassing RMR = 1 (Figure 3b) indicate that the longevity advantage associated with Nicoya has gradually disappeared in recent birth cohorts. For example, compared to the average in Costa Ricans, Nicoyan males born in 1905 had 33% lower adult mortality rates, while those born in 1935 had 4% lower rates and those born in 1945 had 10% higher rates. These are estimates of net cohort effects after controlling for the confounding effects of age and period.

The essentially flat period-effect curves (Figure 3c) suggest that the disappearing longevity advantage of Nicoya is not driven by period effects but by cohort effects.

Figure 3: Model-estimated age, cohort, and period effects on the relative mortality rate (RMR) in Nicoya compared to that in Costa Rica

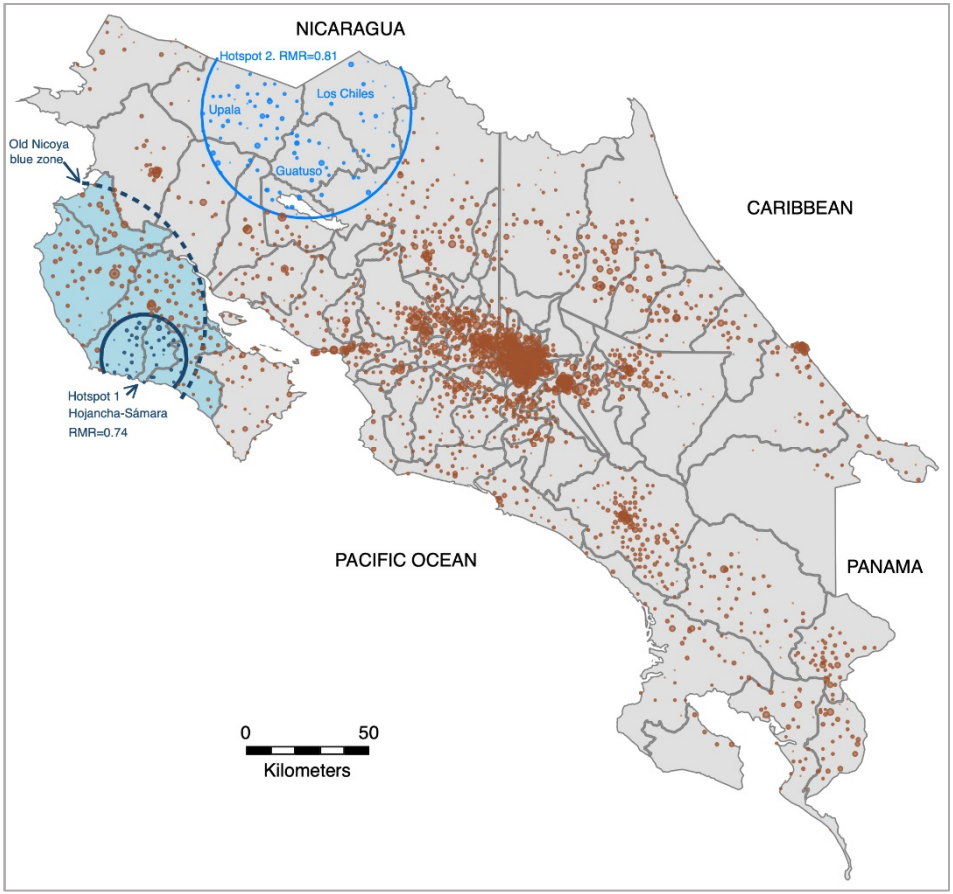


Note: These are marginal effects given average conditions for the other two variables in the model.

Is the Nicoya region still a geographic hotspot of low elderly mortality in Costa Rica? The map in Figure 4 shows the results of the SatScan spatial analysis in the 2010 decade; this analysis was a repeat of the spatial analysis that initially uncovered this hotspot. The map shows the five blue-colored cantons and the dotted semicircle found in the original study that used data from 1990 to 2009 in cohorts born before 1930.

With new data for the 2010 decade and cohorts born before 1950, a small region within the Nicoya Peninsula continues to be the dominant hotspot of low elderly mortality in Costa Rica, with an RMR of 0.74, or 26% lower mortality. The map identifies this new region with a dark blue semicircle, which is substantially smaller than the original blue zone semicircle (dotted line). The new hotspot mainly includes the Hojancha canton and communities south of the city of Nicoya, including Sámara and part of Nosara, both beach towns. The new region had a population in 2022 of 25,000 inhabitants compared to 207,000 inhabitants in the original blue zone. The RMR of the original blue zone was 0.94 in the 2010 decade (supplemental appendix).

Figure 4: Map of hotspots of low elderly mortality detected with SatScan, Costa Rica, 2010–2019



Note: Each point is a voting location. Points are proportional to population size. Canton limits shown.

The emergence of a secondary hotspot (110,000 total population in 2022) of low elderly mortality, indicated by the light blue semicircle on the map, with an RMR of 0.81, is worthy of further research.

4. Conclusions

The death rates estimated for the period 1990–2020 from a nationwide survival-time database of Costa Ricans born before 1950 showed that the exceptionally high longevity of adults in the Nicoya region is disappearing in a trend driven mostly by cohort effects. It also showed that the original geographic hotspot of low elderly mortality has decreased to a small area of 25,000 inhabitants south of the Nicoya Peninsula in the corridor from Hojancha inland to the beach town of Sámara.

A model that simultaneously included age, cohort, and period effects estimated that Nicoyan males born in 1905 had 33% lower adult mortality rates than other Costa Ricans, while those born in 1945 had 10% higher rates. No clear time trend was found for period effects with this model, whereas a clear age effect suggests that the Nicoya longevity advantage comes from middle adulthood. The contemporary disappearance of the Nicoya survival advantage seems rooted in inter-cohort changes that occurred decades ago and in the middle adult ages. More research is needed to confirm this conjecture and to identify the causes of it.

Although the ongoing weakening of the Nicoya longevity advantage is a notable result, another result that must be underscored is that cohorts born before the 1930s continue to show exceptionally high longevity. At present, these exceptional surviving human beings are nonagenarians or centenarians, and the 2020 decade is the last window of opportunity to meet and study these individuals before these cohorts become extinct. By the same token, the remaining small hotspot of low mortality in Hojancha–Sámara might be the last region from which information about improving longevity can be obtained.

A strength of this research note is the robustness of the database. The death rate estimates did not use denominators from a different data source. Rather denominators were obtained from longitudinal follow-up of a 100% sample of individuals whose dates of birth were well documented; thus the sample is free of age exaggeration bias. The possibility of error in the year of birth in the birth ledgers seems nil, especially because late registrations and naturalizations were excluded. Other studies include extensive discussions about why it is unlikely that these administrative data are exaggerating the longevity of Costa Ricans and Nicoyan males (Rosero-Bixby 2008, 2018; Rosero-Bixby, Dow, and Rehkopf 2013).

Loss to follow-up, which could be masking nonregistered deaths, was only 2%. To check how this attrition might affect the estimates, a worst-case scenario in which all losses are considered deaths was simulated. No meaningful change occurred in this simulation compared to the originally observed cohort and period time trends of the relative mortality rate in Nicoya (Figure S1 in the supplementary material).

This article shows that hotspots of extreme longevity are probably transient and their status should be reassessed continuously. This is the first published study reassessing the status in any of the so-called blue zones.

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References

Buettner, D. (2010). The Blue Zones: Lessons for living longer from the people who've lived the longest. Washington, D. C.: National Geographic Society.

Caselli, G., Vaupel, J.W., and Yashin, A.I. (1985). Mortality in Italy: Contours of a century of evolution. *Genus* 41(1–2): 39–55.

Deaton, A. (1997). *The analysis of household surveys: A microeconometric approach to development policy*. Baltimore, MD: The Johns Hopkins University Press. doi:10.1596/0-8018-5254-4.

Glei, D.A., Barbieri, M., and Santamaría-Ulloa, C. (2019). Costa Rican mortality 1950–2013: An evaluation of data quality and trends compared with other countries. *Demographic Research* 40(29): 835–864. doi:10.4054/DemRes.2019.40.29.

HMD (2022). Human Mortality Database. USA and Germany: University of California, Berkeley and Max Planck Institute for Demographic Research. https://www.mortality.org/.

Kulldorff, M. (1997). A spatial scan statistic. *Communications in Statistics-Theory and Methods* 26(6): 1481–1496. doi:10.1080/03610929708831995.

Pérez-Brignoli, H. and López-Ruiz, L.A. (2017). Evaluación de cobertura: estadísticas de nacimiento y defunción Costa Rica 2000–2012. Documento electrónico: Instituto Nacional de Estadística y Censos (INEC).

Poulain, M., Herm, A., Errigo, A., Chrysohoou, C., Legrand, R., Passarino, G., Stazi, M.A., Voutekatis, K.G., Gonos, E.S., and Franceschi, C. (2021). Specific features of the oldest old from the Longevity Blue Zones in Ikaria and Sardinia. *Mechanisms of Ageing and Development* 198: 111543. doi:10.1016/j.mad.2021.111543.

Poulain, M., Herm, A., and Pes, G. (2013). The Blue Zones: Areas of exceptional longevity around the world. *Vienna Yearbook of Population Research* 11: 87–108. doi:10.1553/populationyearbook2013s87.

Rosero-Bixby, L. (2008). The exceptionally high life expectancy of Costa Rican nonagenarians. *Demography* 45(3): 673–691. doi:10.1353/dem.0.0011.

Rosero-Bixby, L. (2018). High life expectancy and reversed socioeconomic gradients of elderly people in Mexico and Costa Rica. *Demographic Research* 38(3): 95–108. doi:10.4054/DemRes.2018.38.3.

Rosero-Bixby, L., Dow, W.H., and Rehkopf, D.H. (2013). The Nicoya region of Costa Rica: A high longevity island for elderly males. *Vienna Yearbook of Population Research* 11: 109–136. doi:10.1553/populationyearbook2013s109.

Statacorp (2020). Stata Statistical Software: release 17. College Station, TX: Stata Corporation.

TSE (2021). División Territorial Electoral que regirá para las elecciones del 6 de febrero del 2022. Decreto 2–2021. San Jose, Costa Rica: La Gaceta.

Vincent, P. (1951). La mortalité des vieillards. *Population* 6(2): 181–204. doi:10.2307/1524149.

Wilcox, D.C., Willcox, B.J., He,Q., Wang, N.C., and Suzuki, M. (2008). They really are that old: A validation study of centenarian prevalence in Okinawa. *The Journals of Gerontology, Series A* 63(4): 338–349. doi:10.1093/gerona/63.4.338.