Statistical Applications in Geographical Health Studies

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Barcelona, 8/05/2006

CHAPTER 5

Software for the analysis of disease mapping data

"Before embarking on a regression analysis it is essential to spend an hour or so, preferably away from the computer, to list the main scientific questions and to think how these can be answered by fitting a series of models. Analyses which follow such thought are always simpler and more incisive than those which are born of uncritical use of the computer or worse, of a stepwise regression program".

David Clayton and Michael Hills

5.1 Introduction.

In previous chapters we have described the concept of geographical epidemiology and why it is of interest to conduct geographical studies to assess hypotheses about the health of human societies. We also described the necessity and importance of quantifying the various characteristics of health and risk factors in order to obtain a series of indicators suitable for use in public health. However when our geographical units were very small we had to take into account the statistical instability of such indicators and to do so we made use of statistical models based on two Bayesian approaches.

The manipulation of this data on health and risk factors will allow us to better understand and deal with many of the processes inherent in each model, and obtain useful outcomes from both the statistical and public health points of view. In the present chapter, we will describe briefly the software which currently allow us to implement the different approaches mentioned in earlier chapters.

5.2 Statistical packages for implementing Bayesian approaches.

SAS version 8 incorporates the procedure NLMIXED which permits the method of adaptive Gaussian quadrature to be applied, as well as methods based on decomposition into Taylor series, for the estimation of random effects[68]. To obtain confidence intervals for the parameters it may estimate the standard error with a conditional mean square error[68]. There are other modules of SAS which also allow us to apply the Pseudo-likelihood and restricted Pseudo-likelihood estimation methods[71].

The most complete programs for carrying out geographical analysis in small areas are MLWIN[7] and the program originally called BUGS (***B**ayesian **I**nference **U**sing **G**ibbs **S**ampling*)[7,103,104].

MLWIN incorporates, among others, the PQL estimation method and also permits the use of MCMC. Through these two methods we may use MLWIN to analyze multiple member-ship models which allow us to incorporate spatial structure in the relative risks. It also incorporates a simple conditional autoregressive model estimated using MCMC[7].

There is currently a version of BUGS for the Windows platform, known as WINBUGS version 1.4.1[104]. This version, and earlier ones, may be obtained free from the web site http://www.mrc-bsu.cam.ac.uk/bugs/ (accessed 23/02/2006) and can be called from R[105].

BUGS originally used the Gibbs Sampling algorithm for obtaining samples of the posterior distribution. It currently also incorporates the more general Metropolis-Hastings methods and automatically detects when the distribution is a conjugate distribution, in which case it performs direct sampling[7]. Table 5.1 taken from Lawson et al.[7] shows the different methods which WINBUGS can implement and the hierarchical in which they are used.

Together with WINBUGS, the program CODA (***C**onvergence **D**iagnostic and **O**utput **A**nalysis*)[106] may also be obtained, which performs a series of diagnoses of convergence for the generated Markov chains which allow us to analyze whether these have reached an equilibrium situation. An updated version of CODA known as BOA (***B**ayesian **O**utput **A**nalysis*)[107] which must be executed under R or S-Plus, is freely available via the web site http://www.public-health.uiowa.edu/boa (accessed 23/02/2006). Note that WINBUGS also allows a series of tests for convergence to be performed without the need for the programs CODA or BOA.

Table 5.1. *Hierarchical order of the sampling methods utilized by WINBUGS.*

Target distribution	**Sampling method**
Discrete	Inversion of cumulative distribution functions
Conjugate	Direct sampling
Log-concave	Derivative-free adaptive rejection sampling
Restricted range	Slice sampling
Unrestricted range	Metropolis-Hastings

The specific module of WINBUGS for fitting spatial models, which also allows creation of maps, is called GEOBUGS[77,78]. The manual for this module describes different examples and functions designed for implementing the prior distributions described earlier. Among these functions are those which allow taking an intrinsic conditional autoregressive Gaussian prior, the prior which assumes the double exponential distribution, and the proper prior. It also permits the non-conditional spatial approach and Gaussian models for Bayesian prediction (Bayesian Gaussian kriging models). For other applications using WINBUGS and MLWIN in the context of disease mapping the reader is referred to the recent book by Lawson et al[7].

To obtain the parameters which define the discrete prior the software usually used is that developed by Böhning et al. called C.A.MAN (***C**omputer **A**ssisted **M**ixtures **AN**alysis*)[108] available free of charge via the web site http://www.medizin.fu-berlin.de/sozmed/caman.html (accessed 23/02/2006).

C.A.MAN incorporates a series of algorithms for obtaining the non-parametric maximum likelihood estimates of the model parameters, i.e. in the case of flexible support. These algorithms are useful for maximizing likelihoods composed of mixtures. In these cases the likelihood may be flat and not concave, making it difficult to find the maximum. Such algorithms may be used in an initial phase to find a preliminary solution which can be refined in a second phase with fixed support using the EM algorithm. The algorithms used are known as the vertex direction method (VDM), vertex exchange method (VEM) and a combination of the VEM with the EM algorithm (VEM/EM)[81,82]. Based on their experience, Böhning et al. classified the algorithms in the following order where > means "is better than", and >> means "is much better than"[83]:

VEM > VEM/EM > EM >> VDM

5.3 Programs for creating disease maps.

One of the most complete programs for manipulating and creating maps with spatial information is MapInfo, currently available as version 7. The GEOBUGS module and SAS also allow simple maps to be created involving health indicators and risk factors.

CHAPTER 6

An application of disease mapping: The Atlas of mortality in small areas in Catalonia (1984-1998)

"Either you apply statistics, or you don't really know what it is"

Juan Ferrándiz

"*Knowing is not enough; we must apply. Willing is not enough; we must do*"

Johann Wolfgang von Goethe

6.1 Introduction.

Health Atlases and the mapping of health indicators in general, has demonstrated its great utility in identifying geographical localizations of health problems, in formulation of hypotheses about disease causes, and in monitoring public health interventions. For example, the first atlases of cancer in the United States identified a strong clustering of areas with high rates of mouth cancer in the south east of the country. A subsequent epidemiological study found the clustering to be associated with the habit of chewing tobacco. Furthermore, some authors, by identifying similarities between non-adjacent areas, have managed to find a risk factor common to these locations. For example, the observation of high lung cancer mortality in some coastal areas of the USA has been attributed to ship building activities involving asbestos exposures during the Second World War[39].

In particular, most atlases of mortality at the small area level present patterns of relative mortality risk for the most important causes of death using maps with a high level of geographical resolution[10]. At the end of the XXth century, the most complete small area Atlas was perhaps the Atlas of mortality of United States[21,109] which in turn influenced the design and features of the first Atlas of mortality in small areas published in Spain[6,13]. These atlases combine many maps of small areas providing information about specific diseases. It is important to choose and combine key information that may have some relevance in the description and atieological study of diseases. This can lead to improvements in the study of health indicators in small area atlases with maps showing time trends in the study region[56,95,110,111,112,113] and the geographical patterns in zones within small areas having a large population[114]. The few small area atlases that have included time trend information[22], have assessed the evolution of mortality indicators by comparing several maps for different time periods. Despite its value, this strategy does not show important information such as the relative mortality risk evolution of each area compared to the overall time trend of all areas combined. Additionally, this strategy may not be parsimonious in a small area health Atlas where many causes of death are considered, because it is important to combine the key geographical mortality information into a display sufficiently comprehensive to permit the different maps presented in the Atlas to be close enough to facilitate their visual comparison.

Our goal was construct a mortality Atlas involving a decomposition of the Autonomous Community of Catalonia into 289 small areas (municipalities or aggregates thereof) and 66 primary health areas of Barcelona city, being a small area but with a large population, for the period 1984-1998. In this Atlas we combine important geographical mortality information into a comprehensive display with specific statistical methods, to obtain the relevant information displayed in the maps. For Catalonia as a whole, these maps presented, using a double-page format, the age adjusted relative risk, significantly high and low relative risk areas, relative risk in Barcelona City with respect to Catalonia and internally with respect to Barcelona, relative risk by age group (0-64 and ≥65) and additionally summarized the relative risk evolution over time in each area in an single map, using geographical and temporal information modeled through bayesian methods as proposed by Bernardinelli et al[89]. Specifically, the atlas uses a strategy to include both: 1) relative risk evolution throughout the study period of each area compared to the average trend for all Catalonia and 2) the absolute relative risk evolution of each area. To our knowledge, this is the first time that both types of information have been combined in a single map. In addition, this is the first Atlas that presents information about geographical patterns in zones within small areas having a large population such as the cities of a country and includes life expectancy obtained with an empirical bayes approach.

In Section 6.2 we explain the methods used in the Catalonian Atlas. Specifically, in section 6.2.1 we explain the geographical unit of analysis, in 6.2.2 the sources of mortality and population information, in 6.2.3 the statistical analysis and in 6.2.4 the geographical methods. The results and selected maps are described in section 6.3. Finally, Section 6.4 contains discussion.

6.2 Methods.

6.2.1 Geographic Unit.

In Catalonia the availability of geographical and statistical data makes it possible to conduct mortality studies at a very small geographical scale. This is the case for example of the 942 municipalities in existence at the time of the 1991 census. However, in order to analyse this information, it was necessary first to solve a number of problems. Firstly, due to the number of deaths in many municipalities was too small to obtain stable death rates. Secondly, for confidentiality reasons, vital statistics legislation restricts the use of mortality information in the smallest municipalities. Thirdly, municipalities were very heterogeneous in their population size. In order to overcome these problems it was necessary to construct small areas or ‘zones’ with similar social and demographic characteristics. Thus, a previous study covering Spain as a whole based initially on municipalities, applied Geographical Information System (GIS) techniques and a method based on three main criteria (contiguity of the small areas, similarity of socioeconomic indicators, and a minimum population size) to construct 2,220 geographical zones with at least 3,500 inhabitants[6,16,115], of which 289 belonged to Catalonia (see appendix A.5). Furthermore, given that Barcelona is a large city, it is important to have data for even smaller areas. For this reason, in the case of Barcelona city, the zones chosen for study are the 66 Primary Health Areas, zones delimiting the area of action of the primary care centres. Although the zones vary in size, they are of approximately 20,000 inhabitants.

In order to facilitate geographical interpretation of the results, maps are included of the provinces (Figure 6.1), of the counties (Figure 6.2) and of the Barcelona Primary Health areas (Figure 6.3).

Figure 6.1 Map of provinces.

Figure 6.2 Map of comarcas (similar to counties).

Figure 6.3 Map of Barcelona Primary Health Areas showing city districts.

6.2.2 Data Sources.

6.2.2.1 Mortality data.

In Catalonia, just in many other countries, the death register is the most complete statistical source of health data for small areas. Thus mortality data constitute a unique resource of easily available indicators in small areas, comparable over long periods. In Catalonia, collection and coding of death certificates follows the World Health Organisation (WHO) recommendations. As several studies have shown, the quality of mortality statistics is comparable to that of other European countries[41,42]. The coding process is performed by a mixed coding centre in which both the Catalan Regional Government Department of Health and the Barcelona city Public Health Agency participate. Deaths are subsequently sent to the Spanish National Statistics Institute (INE). Mortality data is collected for all persons who die in Catalonia, and does not include Catalan residents who die abroad.

The mortality data for the 289 small areas of Catalonia created in our previous studies was obtained from the Spanish National Statistics Institute (INE). This data corresponded to deaths of Catalan residents for all causes and for specific causes of death collected from death certificates coded according to the International Classification of Diseases (ICD), 9th edition. Mortality data for the Barcelona city primary health areas (PHA) was provided by the Barcelona Public Health Agency, and corresponds to deaths of Barcelona residents. Mortality data were provided by area of residence, age, sex, time period (three year periods for Catalonia and year for Barcelona) and cause of death. Subsequently, the data were aggregated by area of residence, sex, 18 5-year groups (0-4, 5-9, …, ≥ 85), 3-year time-period (1984-1986, …, 1996-1998) and specific cause of death.

The total numbers of deaths during the study period of 15 years (1984-1998) were: 360,776 among women, and 399,448 among men, with the number of deaths per area varying widely depending on area size. Of the total, 32% of deaths corresponded to Barcelona (15,8% women and 16,2% men).

Based on the cause-specific mortality data, the 12 leading causes were grouped following a scheme proposed by the Epidemiological Surveillance Unit of the National Epidemiological Centre (Spanish Ministry of Health), based on the ICD-9 list of 50 cause of death groups. Furthermore, four more causes of death were chosen, in addition to the above, for both men and women. Table 6.1 presents the ICD-9 codes, with the corresponding numbers and proportions of deaths, for the specific causes analysed in this Atlas. It should be noted that AIDS was only analysed for the period from 1987 to 1998.

6.2.2.2 Population data.

Population data by sex, age group and time-period, for each of the small areas in Catalonia, came from the censuses of 1981, 1991 and 2001, have been provided by the Catalan Institute of Statistics (IDESCAT). IDESCAT also provided local population censuses for the years 1986 and 1996, which served to validate the inter-census interpolation methods used to estimate the population for each year of the study period. The estimations for inter-census years were carried out taking into account the evolution of the population in age groups over the years (see statistical analysis section).

Table 6.1. Number and proportion of deaths by all causes and by specific causes in women and men, 1984-1998.

Women			**Men**		
Causes of death (ICD-9)	**No.**	**%**	**Causes of death (ICD-9)**	**No.**	**%**
Cerebrovascular diseases (430-438)	56267	15.6	Ischaemic heart disease (410-414)	45090	11.3
All other heart diseases (415-429)	45796	12.7	Cerebrovascular diseases (430-438)	39394	9.9
Ischaemic heart disease (410-414)	33964	9.4	Lung cancer (162)	32552	8.1
Atherosclerosis (440)	17301	4.8	All other heart diseases (415-429)	30967	7.8
Breast cancer (174)	14442	4.0	Chronic obstructive pulmonary diseases (COPD) (490-496)	24634	6.2
Diabetes (250)	11636	3.2	Cirrhosis (571)	12558	3.1
Dementia, Alzheimer (290.0.1,331.0.2.8.9)	10604	2.9	Prostate cancer (185)	11034	2.8
Chronic obstructive pulmonary diseases (COPD) (490-496)	10297	2.9	Traffic injuries (E 810-829)	10435	2.6
Colon cancer (153)	8112	2.2	Atherosclerosis (440)	9287	2.3
Acute respiratory infections, pneumonia and influenza (ARI) (460-466,480-487)	7288	2.0	Stomach cancer (151)	8779	2.2
Cirrhosis (571)	7035	1.9	Colon cancer (153)	8479	2.1
Stomach cancer (151)	5959	1.7	Acute respiratory infections, pneumonia and influenza(ARI) (460-466,480-487)	7207	1.8
Lung cancer (162)	3602	1.0	Diabetes (250)	6896	1.7
Traffic injuries (E810-829)	3430	1.0	AIDS (279.1,279.8,279.5)*	5604	1.4
Suicide (E950-959)	1862	0.5	Dementia,Alzheimer (290.0.1,331.0.2.8.9)	5599	1.4
AIDS (279.1,279.8,279.5)*	1264	0.4	Suicide (E950-959)	4497	1.1
All causes (000-999)	360776	100	All causes (000-999)	399448	100

* In 1985-88 the code was 279.1, in 1988-89 was 279.8 and since 1989 was 279.5.

Population data for the PHA, by sex, age group and time-period were obtained from the municipal censuses of 1986, 1991 and 1996, and from a consultation of the continuously updated municipal census, carried out in December 2000. These data were provided by the Barcelona Public Health Agency (Barcelona City council Department of Statistics). Estimates of the Barcelona population for the period 1986 to 1998 were obtained using the same intercensal estimation methods used for the rest of Catalonia. The population for 1984 and 1985 was assumed to be the same as in 1986.

6.2.3 Statistical Analysis.

6.2.3.1 Population estimates.

National censuses for the years 1981, 1991, and 2001 were used to estimate the population of Catalonia for the intercensal years. As part of the estimation process, a prove was carried out to assess the effectiveness of the method used, which consisted of producing estimates for 1986 and 1996, and comparing these with real data available from the respective municipal censuses. These municipal censuses have been shown to have acceptable reliability in Catalonia. The estimations were carried out taking into account the evolution of the population over the years, yielding better results than those based on linear interpolation from the same age group between two consecutive censuses. Estimations of the population for Barcelona city were obtained using the same method as for the population of Catalonia. This method is explained in the next section.

6.2.3.1.1 Estimation of the population for the central year between two national population censuses.

Let P_{ijk} be the female [male] population at risk in the i-th area, j-th 5-year age-group, and k-th year, where i=1,...,289, j=1,...,18 and k=1,...,20. In order to illustrate the estimation approach used, we present the estimation process for one of the years 1986 or 1996, which we carried out in order to compare results with real data from the municipal censuses for those years. Specifically, we will estimate the 1986 population. The approach is generalizable to any central year between the national censuses of 1981 and 1991, or 1991 and 2001. We assume for the purposes of estimation that immigration and emigration cancel each other out.

Table 6.2. *Evolution of the population.*

AGE		YEAR 1981	1986	1991
	j-1	$P_{i\,j\text{-}1\,1}$		
AGE	j		$P_{i\,j\,6}$	
	j+1			$P_{i\,j+1\,10}$

Consider the above table (Table 6.2). This table indicates that in 1981 there are $P_{i\,j-1\,1}$ individuals in age group j-1, of whom $P_{i\,j\,6}$ remain alive in 1986, moving into age group j, and in 1991 $P_{i\,j+1\,10}$ remain alive, and pass into age group j+1. Thus, in the period between 1981 and 1986 we see that $P_{i\,j-1\,1} - P_{i\,j\,6}$ inhabitants die, while between 1986 and 1991, $P_{i\,j\,6} - P_{i\,j+1\,10}$ inhabitants die.

Let $S_{j\,k,j'\,k'}$ be the probability of passing from age group j in year k to age group j' in year k'. Assuming this probability follows an Exponential distribution, we define the probability of passing from age group j-1 in 1981 to age group j in 1986, and passing from age group j in 1986 to age group j+1 in 1991, respectively as:

$$S_{j-1\,1,j\,6} = e^{-\lambda_{j-1\,1,j\,6}} \quad \text{and} \quad S_{j\,6,j+1\,10} = e^{-\lambda_{j\,6,j+1\,10}} \qquad (6.1)$$

where $\lambda_{j-1\,1,j\,6}$ and $\lambda_{j\,6,j+1\,10}$ are mortality hazards for passing from age group j-1 in 1981 into age group j in 1986, and passing from age group j in 1986 to age group j+1 in 1991, respectively.

From (6.1) we obtain the probability of passing from group j-1 in 1981, to group j+1 in 1991:

$$S_{j-1\ 1,j+1\ 10} = e^{-\lambda_{j-1\ 1,j\ 6}} e^{-\lambda_{j\ 6,j+1\ 10}}$$

Assuming proportional hazards, and κ a proportionality constant,

$$\lambda_{j\ 6,j+1\ 10} = \kappa\, \lambda_{j-1\ 1,j\ 6}$$

we obtain

$$S_{j-1\ 1,j+1\ 10} = e^{-(1+\kappa)\lambda_{j-1\ 1,j\ 6}} \qquad (6.2)$$

It is also possible to obtain another estimate of the probability of passing from group j-1 in 1981 to group j+1 in 1991, as follows[116]

$$\hat{S}_{j-1\ 1,j+1\ 10} = P_{i\ j+1 10} / P_{i\ j-1 1} \qquad (6.3)$$

Equating expressions (6.2) and (6.3) yields the estimate of $\lambda_{j-1\ 1,j\ 6}$ for some fixed κ:

$$\hat{\lambda}_{j-1\ 1,j\ 6} = -\log(P_{i\ j+1 10} / P_{i\ j-1\ 1}) / (1+\kappa) \qquad (6.4)$$

Now, by substituting the estimation of $\lambda_{j-1\ 1,j\ 6}$ into the expression for $S_{j-1\ 1,j\ 6}$ defined in (6.1) we obtain:

$$\hat{S}_{j-1\ 1,j\ 6} = e^{-\hat{\lambda}_{j-1\ 1,j\ 6}} \qquad (6.5)$$

Also, another estimate for $S_{j-1\ 1,j\ 6}$ may be obtained by a procedure analogous to that used to obtain expression (6.3):

$$\hat{S}_{j-1\ 1,j\ 6} = P_{i\ j 6} / P_{i\ j-1 1} \qquad (6.6)$$

Equating expressions (6.5) and (6.6) we obtain the population estimate for the year 1986, age group j, with j=2,...,17

$$\hat{P}_{i\,j6} = P_{i\,j-1\,1}\,(P_{i\,j+1\,10}/P_{i\,j-1\,1})^{1/(1+\kappa)}$$

We now describe the process of estimating the population for the groups aged 0-4 years and ≥ 85 years. In order to estimate the population in 1986 for the group aged 0-4 years, we assume that the mortality hazard in passing from group 0-4 years in 1981 to group 5-9 years in 1986 ($\lambda_{1\,1,\,2\,6}$), is the same as that for passing from the group 0-4 in 1986 to that aged 5-9 in 1991 ($\lambda_{1\,6,\,2\,10}$). Similarly, in order to estimate the 1986 population in the group aged ≥ 85 years, we again assume that the mortality hazards for passing from the group aged 80-84 years in 1981 to that aged ≥ 85 in 1986 ($\lambda_{17\,1,\,18\,6}$), is the same as for passing from the 80-84 year group in 1986 to the groups aged ≥ 85 in 1991 ($\lambda_{17\,6,\,18\,10}$). Under this assumption, and following the same steps described above, for the age groups j=2,...,17, we calculate the population estimates for the groups aged 0-4 and ≥ 85 years:

$$\hat{P}_{i\,j6} = P_{i\,j+1\,10}\,(P_{i\,j\,1}/P_{i\,j+2\,10})^{1/(1+\kappa)} \qquad j=1$$

$$\hat{P}_{i\,j6} = P_{i\,j-1\,1}\,(P_{i\,j10}/P_{i\,j-2\,1})^{\kappa/(1+\kappa)} \qquad j=18$$

With κ equal to 1 we obtained population estimates very close to the true figures from the 1986 municipal census, representing an improvement over the approach based on interpolation between national census data for the same age group (and likewise for our estimates of the 1996 population, compared to the 1996 municipal census). Therefore, we used a value of κ equal to 1 to estimate the population for all other intercensal years.

6.2.3.1.2 Population estimates for each intercensal year.

In order to obtain estimates of the population in the j-th age group for the k-th year between two given national censuses, we used a procedure similar to that described above. Taking κ equal to 1 (value considered optimum as shown above), using T to denote the years of difference between the k-th year and the preceding national census, and L the years between the preceding and following national census years, and:

f=T/L=(k-th year – preceding census) / (following census – preceding census)

it can be shown that the population estimates for the j-th age group in the k-th year are as follows:

$$\hat{P}_{i\,j\,k} = P_{i\,j-1\,1}\,(P_{i\,j+1\,10}/P_{i\,j-1\,1})^{f} \qquad j=2,...,17$$

$$\hat{P}_{i\,j\,k} = P_{i\,j+1\,10}\,(P_{i\,j\,1}/P_{i\,j+2\,10})^{1-f} \qquad j=1$$

$$\hat{P}_{i\,j\,k} = P_{i\,j-1\,1}\,(P_{i\,j\,10}/P_{i\,j-2\,1})^{f} \qquad j=18$$

6.2.3.2 Expected counts of deaths estimates.

In order to handle the confounding effect of age, we opted for the prior calculation of expected death counts. This approach greatly reduced computational time for the estimation process, compared to the method of including age as fixed effect in the model.

The reference rates used to compute expected counts in each cause of death were obtained from a Poisson regression model with eighteen 5-year age group indicators as covariates (0-4, 5-9, .., 80-84, ≥85), where an overdispersion was allowed and estimated, and within-area correlation was accounted for by the use of generalised estimating equation (GEE) approach with an exchangeable working correlation matrix. The GEE Poisson regression model allowed to obtain the reference age rates internally from the data as the approaches proposed by Breslow and Day[54] and Clayton and Kaldor[59].

Let D_{ijt} and P_{ijt} be the number of deaths in women [men] due to a specific cause of interest, and the population of women [men] of the i-th area, j-th 5-year age group and t-th 3-year-time-period, where i = 1, …, 289 (or 66 for Barcelona city), j=1, …, 18 and t=1,...,5. For to obtain the expected cases of deaths of Barcelona with respect to Catalonia we consider together the 288 small areas of Catalonia without Barcelona and the 66 small areas of Barcelona. We denote the sum of D_{ijt} and P_{ijt} across the 5 time periods by D_{ij} and P_{ij}, respectively. The GEE Poisson regression model presents the following log-linear mean:

$$\log (E[D_{ij}]/P_{ij}) = \alpha_j$$

where the α_j are the age-effect parameters. To account for over-dispersion and within-area correlation in the 18 5-year age groups, we considered the second order structure:

$$Var[D_{ij}] = \phi\, E[D_{ij}] \qquad \text{and} \qquad Corr[D_{ij}, D_{ik}] = \rho$$

See Liang and Zeger (1986) for the theory of GEE[34]. The age-specific reference rate Catalonia in the j-th 5-year age group is given by the exponent of the estimate for the parameter α_j.

The expected count of deaths from the specific cause of interest, E_{ijt}, of the i-th area, j-th 5-year age group and t-th time period is given by:

$$E_{ijt} = P_{ijt} e^{\hat{\alpha}_j}$$

The sum of E_{ijt} across all 18 age groups is denoted by E_{it}.

6.2.3.3 Empirical Bayes estimation.

To describe age-adjusted relative risk of mortality, standardised mortality ratios (SMR) are often used. In small area studies, however, the statistical stability of SMR is an issue of special concern. That is, the SMR for an area with a small population size is subject to a large variability and such highly variable SMR tend to dominate spatial patterns in disease maps (see chapter 3). We, therefore, considered statistical model[95], in which the relative risk of mortality in each small area, and its evolution over the study period, were obtained via a empirical Bayes estimation method[59,61].

Let D_{it} and E_{it} be the count, and expected count, of deaths in women [men] due to a specific cause of interest in the i-th area and the t-th 3-year time period, where i=1,…,289 and t=1,…,5. We assume a Poisson distribution on $D_{it}|\beta_i,\delta_i$ with the following log-linear mean:

$$\log (E[D_{it}|\ \beta_i ,\delta_i] / E_{it}) = \beta_0 + \beta_i + (\delta + \delta_i)(t-3)$$

where β_i and δ_i are independent random effects following a Normal distribution with mean 0 and variances σ^2 and τ^2 respectively, i.e.

$$\beta_i \sim \text{Normal}\ (0, \sigma^2) \qquad \text{and} \qquad \delta_i \sim \text{Normal}\ (0, \tau^2)$$

In this model β_0 is the logarithm of the mean relative risk over all areas, β_i the logarithm of the mean relative risk for the i-th area, δ an effect quantifying the mean linear trend in relative risk over all areas, while $(\delta+\delta_i)$ quantifies the linear trend in relative risk for the i-th area.

Thus, δ_i represents the difference between the specific trend of the i-th area and the global mean trend of all areas. When $\delta_i<0$ the evolution of the i-th area is better than that of all areas, whereas if $\delta_i>0$ the specific area presents a worse evolution than that of all areas. If $(\delta+\delta_i)>0$, the trend in the specific area is increasing, while if $(\delta+\delta_i)<0$, it is decreasing. We will refer to the differential trend (DT) of the i-th area as δ_i while $(\delta+\delta_i)$ will refer to the global trend of the i-th area. Following Bernadinelli et al. we also consider the centre of the study period as the origin of the time axis in order to reduce the potential correlation between β_i and δ_i[95]. See the work of these authors for more detail on the model employed.

In order to perform the empirical Bayes estimation of the random effects in this generalized linear mixed model, we used the NLMIXED procedure of SAS 8.0[68] (see general SAS program in appendix A.2). An adaptive Gaussian quadrature method has been used to approximate the marginal likelihood of the fixed effects, and the trust region algorithm for the subsequent optimization. For more details of the estimation procedure, see the manual for the NLMIXED procedure, and the articles by Pinheiro and Bates[117], and Booth and Hobert[118].

6.2.3.3.1 Small areas mortality relative risk.

Once the empirical Bayes estimates have been obtained for the random effects, we proceed to obtain the age-adjusted mean relative risk for the i-th area, θ_i, from:

$$\hat{\theta}_i = e^{\hat{\beta}_i}$$

In order to made the small area maps with the geographical relative risk distribution we computed seven groups from low to high relative mortality risk (i.e. septiles).

In addition, we create maps which indicate high-risk areas and low-risk areas of each cause of death. The areas of high [low] risk are defined according to whether $\hat{\theta}_i$ > 1.0 [< 1.0] and a significance level of 5% for testing θ_i=1. For the set of all high risk areas, the distribution of $\{\theta_i\}$ is calculated, defining areas having a “very high” risk, or “high” risk according to whether their θ_i estimates fall in the upper quartile of the distribution, or in that above the median of the distribution, respectively. The sets of low risk areas were classified as “very low”, and “low” in a analogous manner.

6.2.3.3.2 Evolution of relative risk of mortality.

To construct maps showing the evolution of relative risk for each area compared to the trend for Catalonia as a whole, areas were classified according to their DT estimates $\{\hat{\delta}_i\}$. Areas with $\hat{\delta}_i \geq 0.01$ [≤ -0.01] were considered to have a worse [better] evolution than the general trend in Catalonia. These cut off points were chosen in order to exclude those areas in which $\hat{\delta}_i$'s were negligible.

Within the areas having worse evolution, three groups were created. The first group consists of those areas with a significant DT at the 5% level. For the areas with non-significant DT the distribution $\{\delta_i\}$ was calculated and the second and third groups defined as those areas having δ_i estimates in the upper quartile, and above the median, respectively. For the set of areas with a better evolution a similar procedure was used, with the areas with significant DT in one group, and the remaining two groups being composed of non-significant areas having DT in the lower quartile, or below the median of the distribution of δ_i respectively.

It should be noted that, based on the differential trend alone, it is not possible to determine whether the trend in an area is rising or falling. For example, it may happen that an area presents a worse evolution than that for Catalonia as a whole, and yet have a declining trend over the study period. Hence, additional information has been included next to the color key for the area-specific differential evolution, the range of values expressed as the change in relative mortality risk (SMR-C) for each 3-year period. The change occurring in the relative risk of each area over each 3-year time-period has been obtained from

$$e^{(\hat{\delta}+\hat{\delta}_i)}$$

In this way, in addition to classifying the evolution of the areas with respect to the general trend for Catalonia, one may also see just what the overall trend was for the areas forming a particular group. Thus, if $e^{(\hat{\delta}+\hat{\delta}_i)}>1$ the global trend of the i-th area is increasing, and if $e^{(\hat{\delta}+\hat{\delta}_i)}<1$ it is decreasing.

6.2.3.4 Life expectancy estimates.

To obtain life expectancy in the i-th area, the approach proposed by Congdom[119] was used. This approach minimises the problem of statistical instability in the age-specific mortality rates for small areas. In our case, an empirical Bayes model was used to obtain the age-specific mortality rates in each area and 5-year age-group. The calculation of life expectancy in each area was carried out for the 0-4 years age group. The results were obtained for men and for women in the time-periods 1987-1992, and 1993-1998.

Let O_{ij} and N_{ij} be, respectively, the count of all deaths among women [men] in a period of time (1987-1992 or 1993-1998) and the women [men] population at risk, in the i-th area, and j-th 5-year age group, where i=1,…,289 and j=1,…,18. We assume a Poisson distribution on $O_{ij}|\mu_{ij}$ with mean:

$$E[O_{ij} \mid \mu_{ij}] = \mu_{ij} N_{ij}$$

where μ_{ij} is the specific mortality rate of the i-th area and j-th age group. This is defined by means of the following log-linear relationship:

$$\log (\mu_{ij}|\beta_i) = \beta_0 + \beta_i + \alpha_j$$

where β_i are independent random effects with a Normal distribution having mean 0 and variance σ^2, which represent the effect of the i-th area, and α_j are fixed effects, representing the effect of the j-th age group.

Once β_0, β_i and α_j have been estimated using the NLMIXED procedure, we may obtain an estimate for μ_{ij}. Based on this estimate, the life expectancy in the j-th age group is obtained by the usual calculation procedure for an abridged life table[119,120].

Software programmes used in statistical analyses included S-Plus 2000, SAS 8.0, SPSS 9.0 and Excel.

6.2.4 Geographic Methods.

Maps are accessible and comprehensible tools for epidemiologists, geographers, public health researchers and the public in general that convey instant visual information about spatial patterns in mortality data that words or statistical tables cannot easily express (see chapter 1). However, just as in the Atlas of Mortality in Small Areas in Spain, published previously[6,13], given that there is no ideal way of visualizing spatial information, and all approaches have advantages and disadvantages, we decided to use choropleth (area-shaded) small-area maps since they are the most widely used and understandable method for identifying geographical patterns in mortality[121,109]. In order to best show the changes in risk patterns, and to facilitate comparisons between maps, we used range of values (risk septiles), and colour scheme (divergent, except in those supplemental).

In the present Atlas of Mortality we have used the same colour scheme already employed in the Spanish Atlas of Mortality[6], as it is effective for representation of quantitative data. Furthermore, the sequence of tones can, with care, be interpreted correctly by persons with colour-blindness[45]. The divergent hues for the colour schemes are very similar to those used by the Spanish Atlas of Mortality. In the maps of the twelve leading causes of death displayed in a double-page format, we have used a scheme with darker colours towards the extremes of the septiles scale, and lighter colours in the middle. In order to obtain good visual comparability between the maps (Catalonia for the whole period, maps of Barcelona, two age groups, high and low risk areas, trends in risk) we have used a similar sequence. The software used to store, manage, analyse map the digital spatial information was MapInfo 7.0.

6.3 Results.

The twelve leading causes of death in each of the two sexes (Table 6.1) represent 63.4% of mortality among women, and 60.2% among men in the period studied (1984-1998). Among women and men the leading causes of death belong to the group of cardiovascular diseases. However, in men lung cancer occupies third place. In more detail, cerebrovascular diseases are the leading cause among women, and the second among men, whereas ischaemic heart disease is third among women but first among men. The leading three cardiovascular diseases account for 37.7% of female mortality, and 28.9% of male mortality. Among men, lung cancer causes 8.1% of deaths, and chronic obstructive pulmonary disease, 6.2%. In both sexes, all the remaining causes contribute less than 5% of deaths.

In the following sections we describe all causes of death jointly and some selected causes of deaths in women and men. Specifically, we describe cerebrovascular diseases, atherosclerosis and dementia, Alzheimer's disease in women. On the other hand, we describe lung cancer, traffic injuries and stomach cancer in men. The aim is not an exhaustive interpretation of all maps, but rather simply present an overall view of the main geographical patterns, identify areas with high and low risk, and show the evolution over time experienced by the risk, with respect to the general trend in Catalonia.

6.3.1 Women.

6.3.1.1 All deaths.

Total age adjusted mortality among women presents a declining trend in recent years. In Catalonia women have a high life expectancy (83.4 years in the year 2002), well above the mean of European Union countries[122].

Mortality from all causes of death (ICD-9: 000-999) shows a territorial distribution with a concentration of areas of higher risk in the southern half of the country (map for all deaths). The highest levels of mortality occur particularly in the south of Lleida (Segrià and Garrigues *comarcas*), south (Montsià and Baix Ebre) and north of Tarragona (Alt Camp and Baix Penedès) and certain areas in the south of Girona.

Among the areas with highest risk (maps of high and low risk) those situated in the south of the provinces of Lleida (Segrià) and Tarragona (Montsià and Baix Ebre) stand out. In contrast, areas with lower mortality are above all located in the north of the provinces of Lleida and Barcelona.

The risk is low in Barcelona city. When Barcelona city primary health care areas are analysed, it is found that there is a higher mortality risk in the coastal fringe and the north of the city, corresponding to the old city centre (Ciutat Vella) and to certain neighbourhoods constructed during the 1960s to accommodate immigrants from other parts of Spain. These areas also present unfavourable socioeconomic indicators. The primary health areas of the city districts of Les Corts and most of Sarriá-Sant Gervasi (wealthier areas) are the ones which present the lowest risks; this also happens in some areas in the centre of the city.

Among women aged under 65 years (map 0-64 years) the higher number of areas of risk in Lleida, particularly in the west, in the east of Girona (Baix Empordà) and some areas in the north of Tarragona stand out. Among women aged over 64 years (map 65 years and over) the distribution is very similar to that for total mortality.

In general, mortality from all causes presents a declining trend as may be appreciated from the graph showing trends in relative mortality risk during the period studied (graph of the evolution in Catalonia). The areas where the trend in relative mortality risk is above that for Catalonia as a whole are particularly located in the province of Barcelona and scattered areas in the provinces of Lleida and Tarragona (map of evolution in risk). These areas with a worse evolution compared to Catalonia as a whole are concentrated in *comarcas* around the city of Barcelona, and particularly in Vallès Occidental, Vallès Oriental, Osona and Garraf.

6.3.1.2 Cerebrovascular diseases.

Cerebrovascular diseases (ICD-9: 430-438) are the leading cause of death in women, 15.6% of all deaths. Deaths due to this cause have been diminishing in Catalonia since the 1980s[122].

The territorial distribution of areas of high mortality risk are scattered around the four provinces (map of cerebrovascular diseases). Of particular note are the western areas of Lleida (Segrià and Segarra *comarcas*), while in Tarragona there are more risk areas concentrated in the south (*comarcas* of Montsià and Baix Ebre) and the coastal fringe (Tarragonès and Baix Penedès). In Barcelona province the centre (Bages and Vallès Occidental), stand out, along with the south of Girona (area of confluence of Baix Empordà, Gironès and Selva *comarcas*).

The areas with highest risk (map of high and low risk) are mainly in western Lleida, the south of Tarragona (Montsià and Baix Ebre *comarcas*) and a few parts of the central fringe of Barcelona province. The lowest risk areas are to be found in the north of Lleida, coastal Barcelona, and Alt Empordà in Girona.

Barcelona city in general has low risks. With regard to the primary health areas of Barcelona city, the pattern observed is similar to that for all deaths: excess of mortality in the coastal and northern areas, and lower risks for areas corresponding to the wealthier districts (Les Corts and Sarriá-Sant Gervasi), as well as certain areas of the city centre.

Among women aged under 65 years (map of 0-64 years) the above mentioned pattern is maintained. However, there are more areas with high mortality in the west (Noguera) and east of Lleida province (*comarcas* of Segarra and Urgell) while in the provinces of Barcelona and Girona, the pattern is less clear. Among those aged over 64 (map 65 years and over) the mortality pattern is similar to that for total mortality.

Evolution of the relative mortality risk for cerebrovascular diseases presents a clear declining trend over the entire period studied (graph of the evolution in Catalonia).

Areas having a trend in relative mortality risk above that of Catalonia, although spread throughout all four provinces, are of particular note in the *comarca* of Vallès Oriental and the province of Barcelona in general (map of evolution in risk). The areas with the steepest downward trend are to be found in Barcelona and in the north of Tarragona.

6.3.1.3 Atherosclerosis.

Atherosclerosis (ICD-9: 440) is the fourth most frequent cause of death among women, with a total of 4.8% of deaths. The evolution shows a marked decline during the 1980s and 1990s in Catalonia[122].

This cause is basically concentrated in the province of Girona, and to a lesser extent in Barcelona and the other provinces (map of atherosclerosis). Of particular note are the *comarcas* of Estany, Baix Empordà and the southern part of Gironès, all province of Girona. Areas of high risk are more numerous in the *comarcas* of Vallès Occidental and Bages (Barcelona province), as well as in Segrià (Lleida), and Montsià (Tarragona).

Areas where the risk is highest (map of high and low risk) are to be found in the *comarcas* of Baix Empordà (Girona), Vallès Occidental and Alt Penedès (Barcelona), and Segrià (Lleida). Low risk areas are found specially in Osona and Vallès Oriental, both in the province of Barcelona.

The risk is medium in Barcelona city. In terms of primary health care areas, this cause of death has a behaviour opposite to that of most other causes. In this case the coastal and northern zones (poorer areas) have lower mortality, and it is the city centre and wealthier areas where mortality is higher.

Since for this cause, there are practically no deaths in the group aged under 65, the analysis is for the groups aged 65 to 84 years, and 85 years and over. In women aged 65 to 84 the pattern mentioned is partly maintained although there is a rise in number of zones of risk in eastern Lleida (Segarra comarca), and in the west (Anoia and Bages *comarcas*) and south (Garraf and Alt Penedes) of Barcelona province. Among those aged over 85 and over there are certain changes with respect to the general pattern: a notable absence of high risk areas in the *comarca* of Estany (Girona province), while in Lleida the areas of high risk tend to be the northern *comarcas*.

The evolution of relative mortality risk in atherosclerosis presents a clear declining trend (graph of evolution in Catalonia). The areas with a trend in relative risk above that of Catalonia as a whole are spread across all provinces although certain areas stand out, such as Barcelonés *comarca* in the province of Barcelona and northern Lleida (map of evolution of risk).

6.3.1.4 Dementia, Alzheimer's disease.

This group includes senile and presenile dementia (ICD-9: 290.0 and 290.1), Alzheimer's disease (331.0), Senile degeneration of brain (331.2), and Other cerebral degeneration (331.8 and 331.9). It constitutes the seventh cause of death among women, accounting for 2.7% of mortality. Available data on the evolution of mental conditions (290-319) shows clear and constant growth since the beginning of the 1980s[122].

The territorial distribution of risk areas shows concentrations above all in zones near the Barcelona coast (Vallès Oriental and to a lesser extent Vallès Occidental) (map of Dementia, and Alzheimer's disease). Also of note are some zones of the province of Tarragona: north (Conca de Barberà and Alt Camp), central (Priorat) and south (Baix Ebre).

Areas with the highest risk (map of high and low risk) are found particularly near the Barcelona coast (Vallès Oriental and Vallès Occidental). Also notable are a few isolated areas in the south of Tarragona province. There are very few zones with extremely low mortality risk.

The risk in Barcelona city is very low. With respect to the primary health areas, there is no clear distribution pattern in mortality, with zones of both high and low mortality risk scattered over the whole city. Eixample has several areas with high risk.

In women aged under 65 years (map 0-64 years) the pattern of general mortality is limited to the interior, with zone of high risk at the point of confluence of Bages, Anoia and Solsonès *comarcas*, in Segrià *comarca* in Lleida, and Terra Alta in Tarragona. Among women over 64 (map of 65 years and over) the pattern is very similar to that for total mortality.

The evolution of mortality from dementia and Alzheimer's disease in Catalonia as a whole presents a strong upward trend (graph of the evolution in Catalonia). The areas with a relative mortality risk trend above that experienced by Catalonia are concentrated in Barcelona province, particularly Vallès Oriental and some part of Bages (map of the evolution of risk).

6.3.2 Men.

6.3.2.1 All deaths.

Total mortality in men, adjusted for age, shows a declining trend in most age groups. Life expectancy (76.9 years in 2002) is above the average for the European Union, although it does not occupy such a high rank position as for women[122].

Mortality among men from all causes of death (ICD-9: 000-999) shows a very specific territorial distribution (map for all deaths) with zones of greater mortality being concentrated particularly along the coastal areas of Catalonia. In Girona, the *comarcas* of Baix Empordà and Selva stand out, in Barcelona province mortality is concentrated in the coastal *comarca* of Vallès Occidental and also in Bages, in Tarragona in the *comarcas* of Tarragonès and Baix Ebre, while for Lleida it is concentrated in Segrià.

The areas with highest risk (map high-low risk) are concentrated mainly along the Catalan coast, especially in the south of Barcelona and north of Tarragona provinces. The areas with low risk are mostly in the west of Lleida province.

In Barcelona city the risk is high. Within the city, in terms of primary health areas, higher risk is found in coastal and northern areas, specifically the districts of Ciutat Vella, Sants-Montjuïc, Sant Martí as well as parts of Nou Barris and Sant Andreu. The wealthier areas (Les Corts and Sarriá-Sant Gervasi) present the lowest risk, although there are also zones of low risk in the central city. This distribution corresponds to that of socioeconomic indicators, with excess mortality in the poorer areas.

In men aged under 65 years (map 0-64 years) the coastal pattern described above is generally maintained. However mortality is also notable in some western areas of

Lleida, and in northern Catalonia, at the confluence of the provinces of Girona, Barcelona and Lleida (Cerdanya, Berguedà and Ripollès *comarcas*). In men aged over 64 years (map 65 years and over) the distribution is very similar to that for total mortality.

The evolution of total mortality generally presents a declining trend (graph of the evolution in Catalonia). The areas with a trend in relative mortality risk higher than Catalonia are particularly located in Barcelona province. Specifically, most of the zones which have experienced a poor evolution are concentrated in *comarcas* around Barcelona city, particularly Vallès Oriental and Anoia (map of the evolution of risk.

6.3.2.2 Lung cancer.

Lung cancer (ICD-9: 162) is the third cause of death among men, with 8.1% of deaths. This cause was tending to increase until the mid 1990s, when it stabilized and in recent years appears to decline slightly[122].

Lung cancer mortality follows are unique territorial distribution (map of lung cancer) where greatest mortality is around Barcelona city and along the coast. In Barcelona province high mortality occurs in Vallès Occidental, Baix Llobregat, Maresme and Osona *comarcas*, and in Girona there is a notable area is the south of Baix Empordà.

High risk (map high-low risk) is concentrated near Barcelona city and in several coastal areas. In contrast significantly low mortality areas are located in eastern Lleida

In Barcelona city the risk is very high. Within the city, the coastal primary care areas of Sants-Montjuïc, Ciutat Vella and Sant Martí) present high risk, as well as the northern city areas of Nou Barris and Sant Andreu. The main city centre (Eixample and Gràcia) and districts of Sarriá-Sant Gervasi and Les Corts, present the lowest risk.

In men aged under 65 years (map 0-64 years) the coast-oriented pattern, along with Barcelona province, is maintained although high risk areas also appear in Alt

Empordà (Girona). In men aged over 64 years (map 65 years and over) the distribution follows that of total mortality.

Lung cancer mortality presents a stable trend (graph of the evolution in Catalonia). Relative mortality risk is different from Catalonia in general in very few areas, mainly located in Barcelona province where it is higher (map of the evolution of risk).

6.3.2.3 Traffic injuries.

Traffic injuries (ICD-9: E 810-829) are the eighth cause of death in men, with 2.8% of deaths. Traffic injury mortality in Catalonia was rising during the 1980s, reached a peak in 1990, and has been declining since[122].

The territorial distribution of high risk areas show concentrations particularly in Lleida province, north Girona and north Tarragona (map of traffic injuries). There is a cluster of high risk zones at the confluence of the provinces of Lleida, Barcelona and Tarragona (i.e. *comarcas* of Anoia, Segarra, Solsonès, Conca de Barberà, Alt Camp). In Girona there is a clustering affecting Alt Empordà, Estany and Garrotxa *comarcas*, while Tarragona has high risk in Conca de Barberà, Alt Camp, Baix Penedès and Tarragonès.

Regarding the extremes of risk (map high-low risk) most notable is the cluster consisting of Alt Empordà, Estany and Garrotxa *comarcas* in Girona, Segarra and Segrià *comarcas* in Lleida and some zones of northern and southern Tarragona. Significantly low risk areas on the other hand are concentrated around Barcelona city.

In Barcelona city the risk is low. In term of primary care areas this cause shows a fairly random distribution, although certain zones of high risk appear for the central city area (Eixample and Gràcia) and those of a few other districts.

In men aged under 65 years (map 0-64 years), the pattern is very similar to that for total mortality. In those aged over 64 years (map 65 years and over) the mortality pattern is also similar to total mortality.

The evolution of traffic injury mortality presents an increasing trend in the first part of the study period, followed by a decline in the second half (graph of the evolution in Catalonia). Limiting analysis to only the last three time periods, one may observe how the areas with a trend in relative mortality risk above that for Catalonia as a whole are concentrated in the entire province of Lleida and, to a lesser extent in Tarragona (map of the evolution of risk).

6.3.2.4 Stomach cancer.

Stomach cancer (ICD-9: 151) is the tenth cause of death among men with 2.2% of deaths. Mortality from this cause has been declining in Catalonia during the 1980s and 1990s[122].

The territorial distribution of areas of risk (map of stomach cancer) clearly shows a geographical pattern with higher risk in *comarcas* of the interior of Catalonia, such as the centre of Lleida province, western Girona and the north of Barcelona province. In Lleida *comarcas* of note are in the east such as Urgell, Segarra and Solsonès, and northern areas on the French border. In Barcelona, *comarcas* with more zones of risk are Berguedà and Osona, while in Girona, Ripollès, Garrotxa and Estany stand out.

The areas of significantly high risk (map high-low risk) fall in western Girona province, with a few dispersed throughout Lleida.

In Barcelona city the risk is low. In the distribution by primary health care areas, excess mortality affects the coastal and northern parts of the city, just as in the pattern for total mortality. In addition, certain primary care areas in the district of Horta-Guinardó also present elevated risks. The zones of low risk correspond to Eixample and the districts of Sarriá-Sant Gervasi and Les Corts.

In men aged under 65 years (map 0-64 years), the pattern is similar to that already described, where there are two clear clusters of high risk: one around the *comarcas* of Segarra and Solsonès, and another in the *comarcas* of Ripollès, Garrotxa and Estany. In men over 64 years (map 65 years and over) the mortality pattern is similar in general terms to that of total mortality in Girona and Barcelona provinces, but some of the risk areas of eastern Lleida disappear.

The evolution of stomach cancer mortality presents a declining trend (graph of the evolution in Catalonia). The areas where the relative mortality risk has a trend above that of Catalonia lie mainly on the boundary between Barcelona and Lleida (map of the evolution of risk).

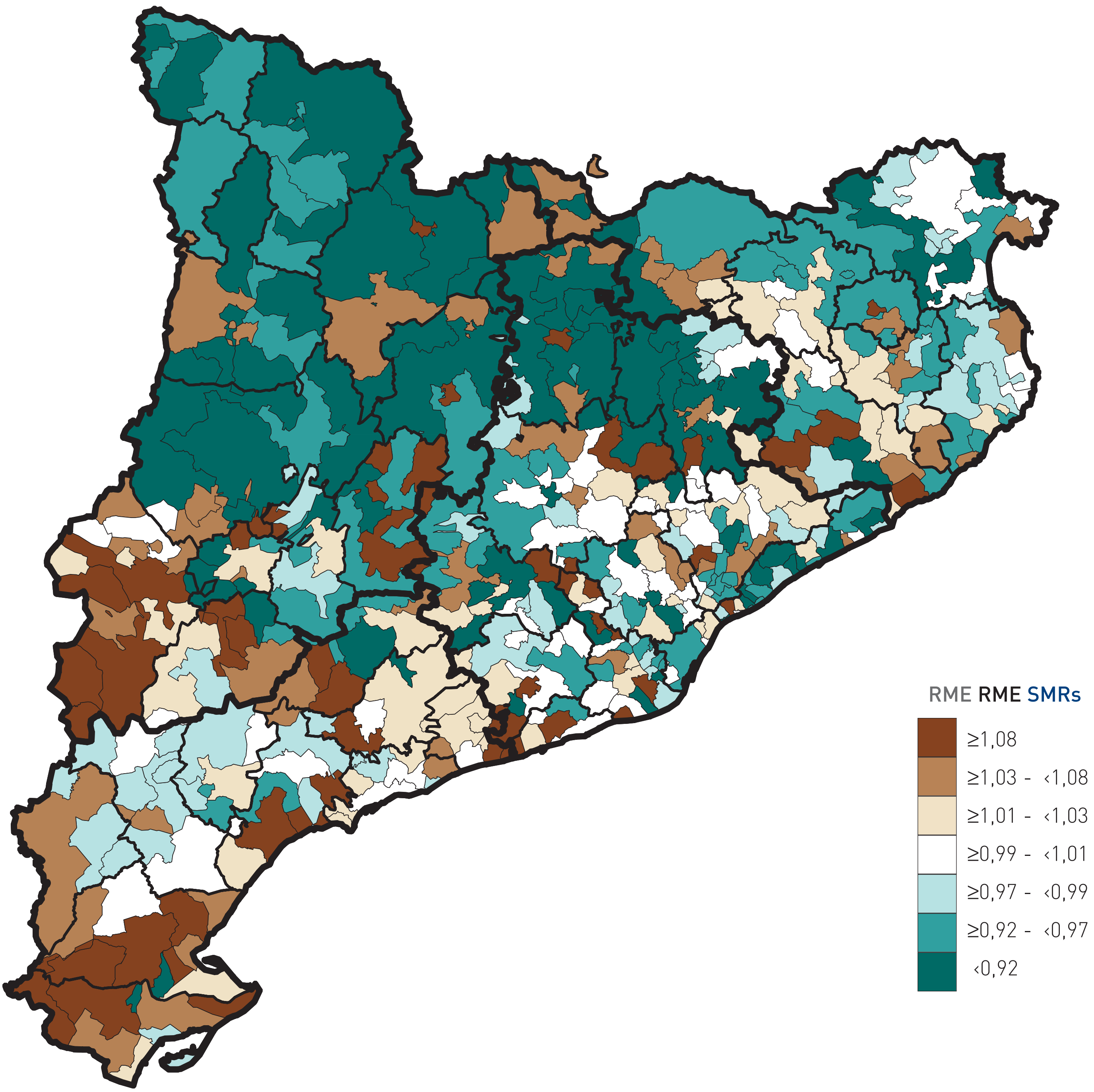
6.3.3 Maps.

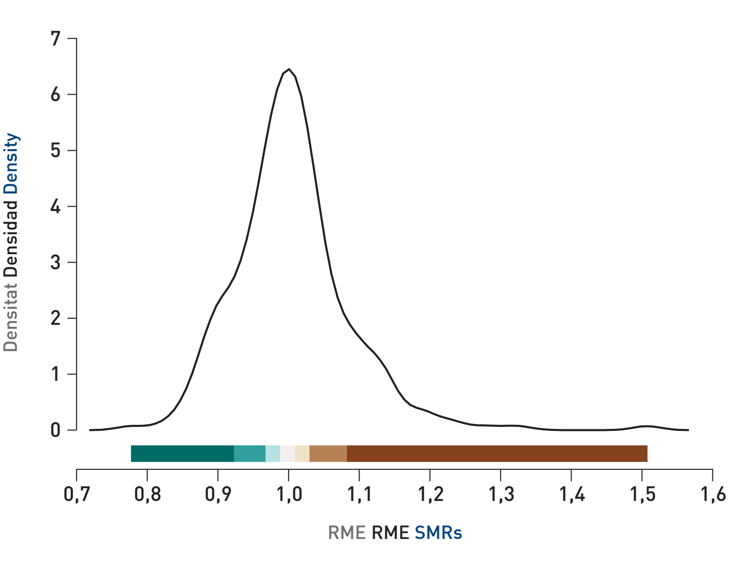
In this section, we present mortality maps for the selected causes of death among women and men. We employ a double-page format, to present maps for each sex and each of the 12 leading causes of death. The first page includes: (a) a large map showing the estimated relative risk with respect to total mortality in Catalonia, (b) a graph of the estimated relative risk density function and (c) a small map showing the statistically significant high and low risk areas. The second page includes: (d) two small maps showing the estimated relative risk for the 66 primary health districts of Barcelona city with respect to total mortality in Catalonia, and within the city itself, (e) two small maps of Catalonia of the relative risk estimate in the age groups under 64 years, and 65 years and over, and (f) a graph of the general trend in mortality for the cause in question over the study period (1984-1998) along with a small map which compares the trend in each area with respect to the trend for Catalonia as a whole, and indicates those areas where the was trend significantly different from that for Catalonia. In addition the map showing the behaviour of the trend in relative risk for each area also includes, next to the colour scale for the groups of areas, the change in relative mortality risk for each three-year period. Thus in addition to classifying the evolution of the areas with respect to the global trend for Catalonia, one may observe what the global trend has been in the areas forming each group.

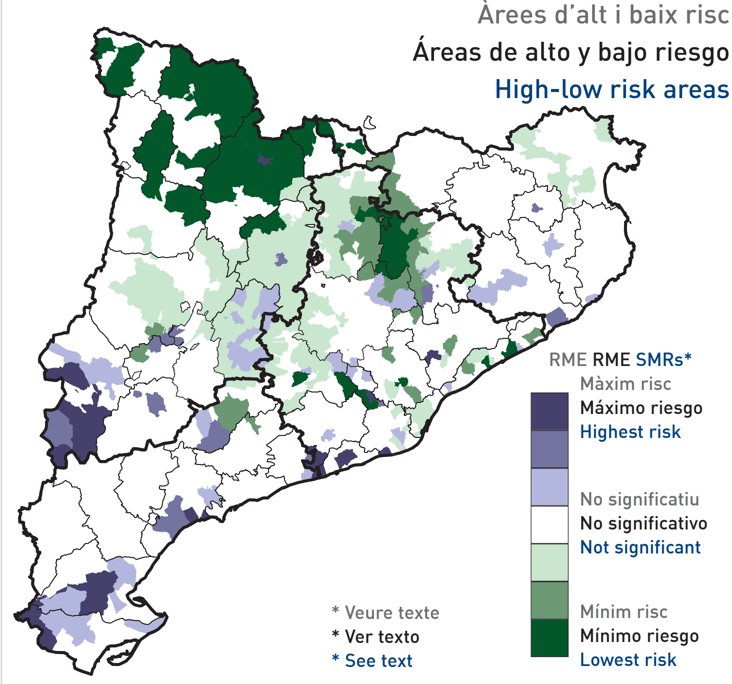
It should be noted that an empirical Bayesian method has been used to obtain the relative mortality risks of the small areas and to quantify their temporal evolution over the study period (see section 6.2.3.3). This method yields smoothed standardised mortality ratios (SMRs) as the estimator for the age-adjusted relative risk of death.

Finally, the appendices provide complementary maps of mortality (life expectancy).

Raons de mortalitat estandarditzades (RME) | Totes les causes - Dones (CIM-9: 000-999)
Razones de mortalidad estandarizadas (RME) | Todas las causas - Mujeres (CIE-9: 000-999)
Standardised mortality ratios (SMRs) | All deaths - Women (ICD-9: 000-999)



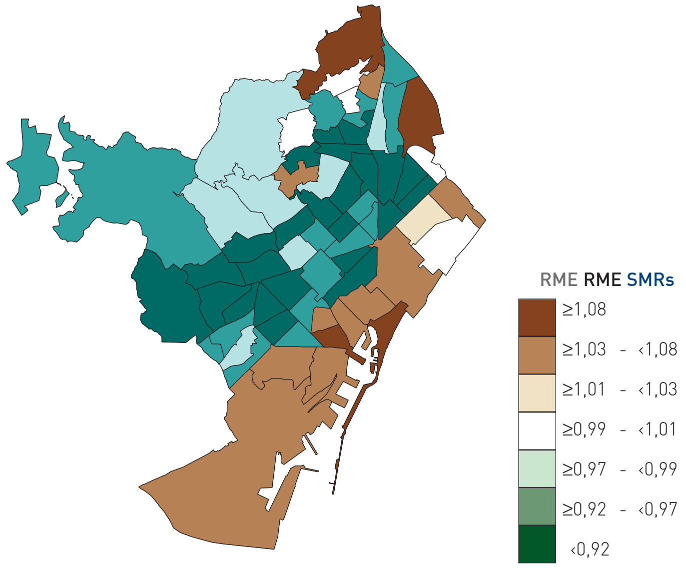




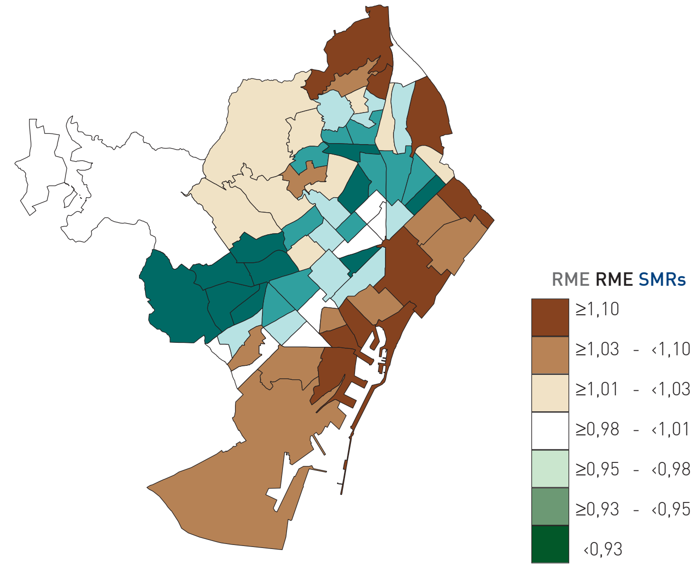
Raons de Mortalitat Estandaritzades (RME)
Razones de Mortalidad Estandarizadas (RME)
Standardised Mortality Ratios (SMRs)

Totes les Causes - Dones (CIE-9: 000-999)
Todas las Causas - Mujeres (CIE-9: 000-999)
All deaths - Women (ICD-9: 000-999)

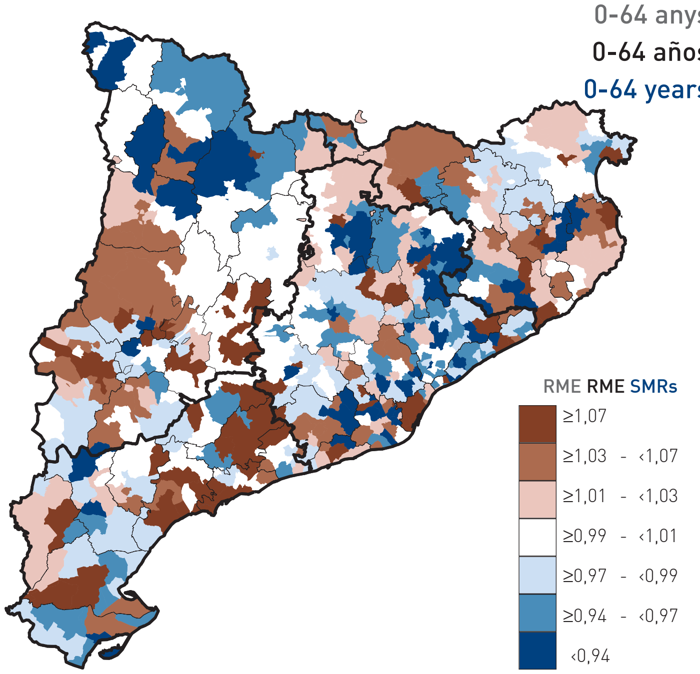
Àrees de Barcelona en comparació amb Catalunya
Áreas de Barcelona en comparación con Cataluña
Barcelona areas vs Catalonia



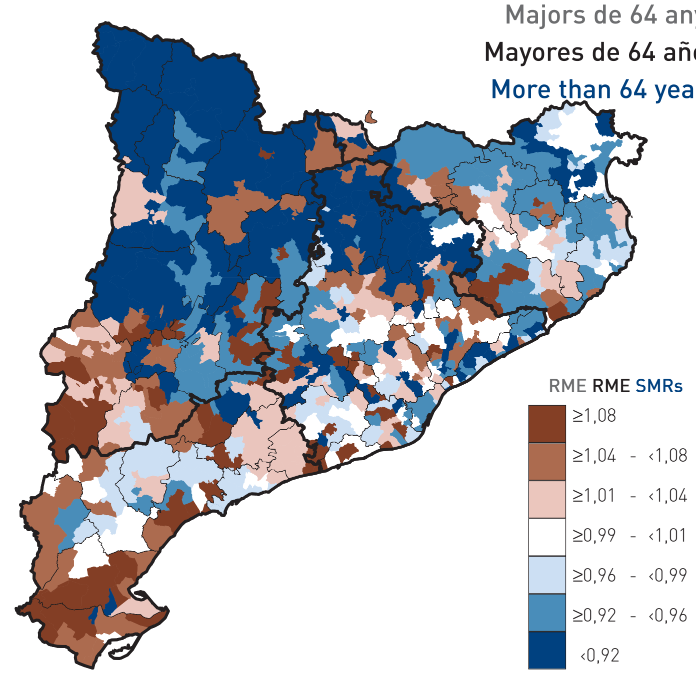
Àrees de Barcelona
Áreas de Barcelona
Barcelona areas



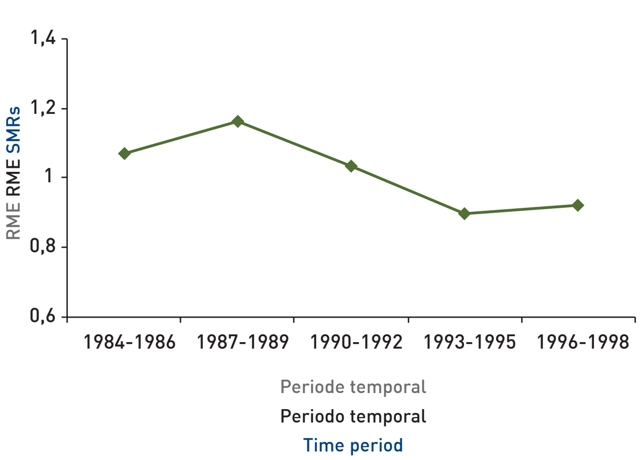
0-64 anys
0-64 años
0-64 years



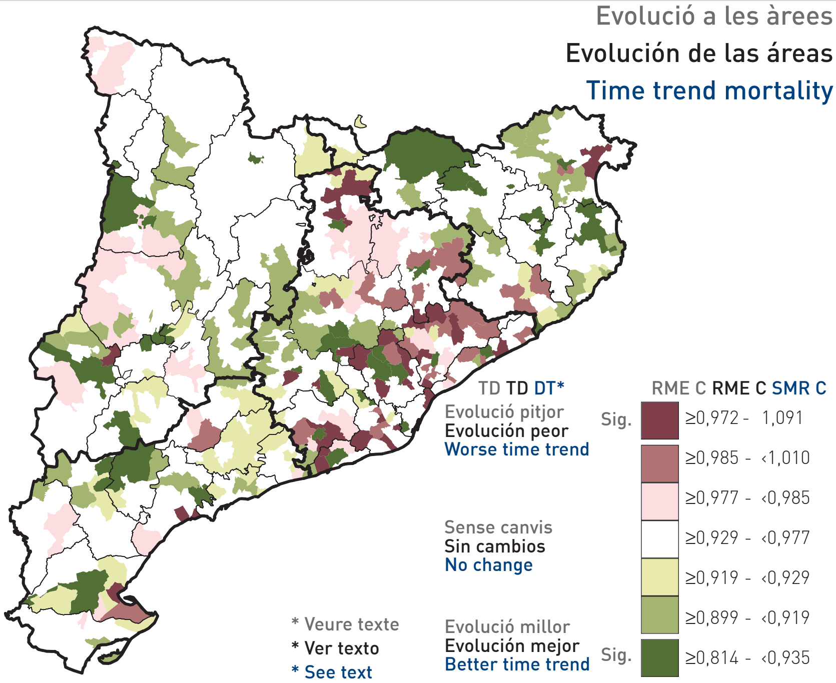
Majors de 64 anys
Mayores de 64 años
More than 64 years

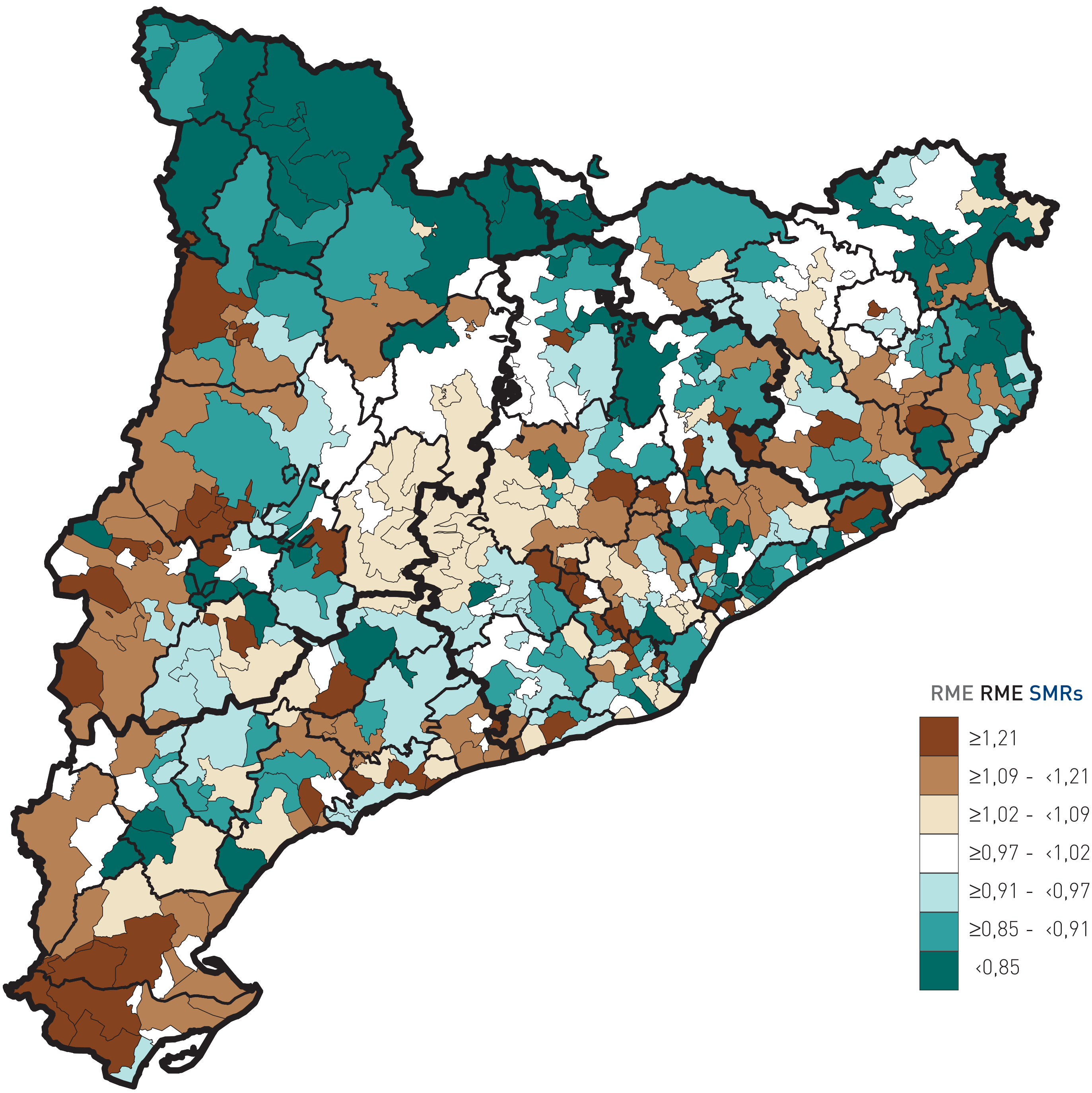


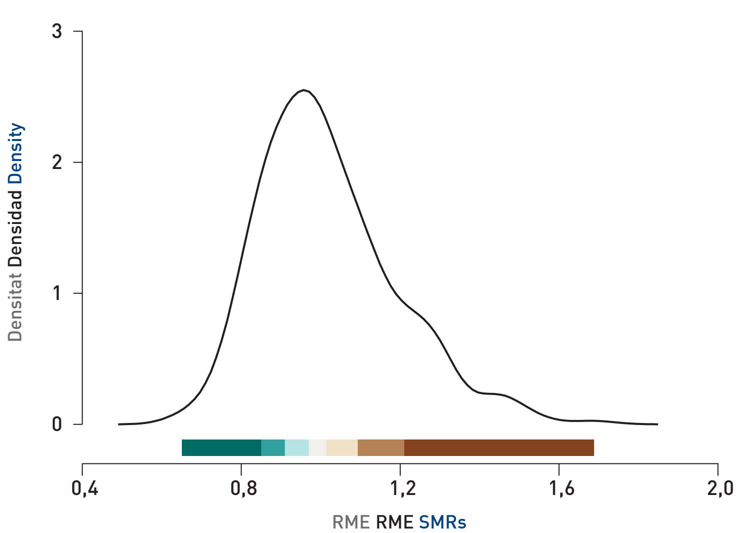
Evolució de la mortalitat a Catalunya (1984 -1998)
Evolución de la mortalidad en Cataluña (1984-1998)
Catalonia time trend mortality (1984-1998)

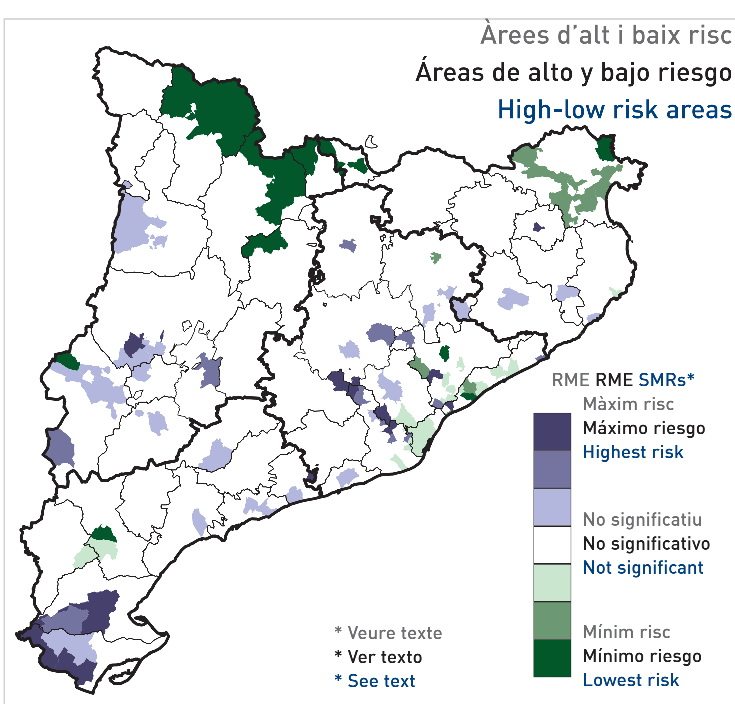


Evolució a les àrees
Evolución de las áreas
Time trend mortality

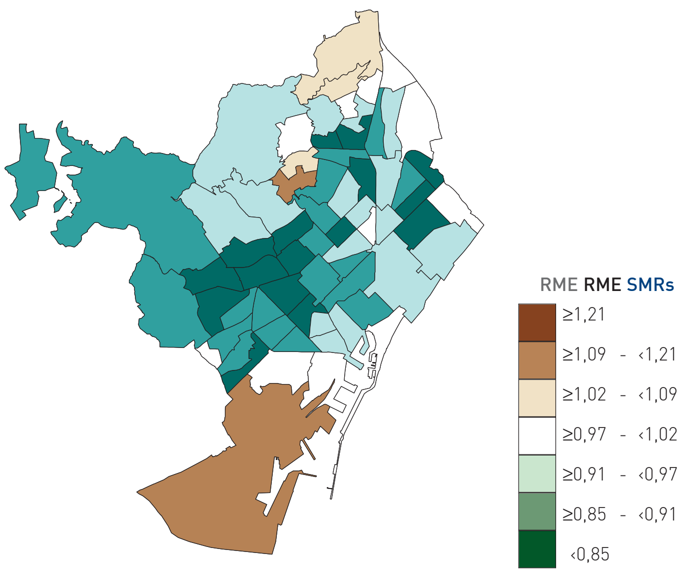



RME RME SMRs
≥1,21
≥1,09 - ‹1,21
≥1,02 - ‹1,09
≥0,97 - ‹1,02
≥0,91 - ‹0,97
≥0,85 - ‹0,91
‹0,85

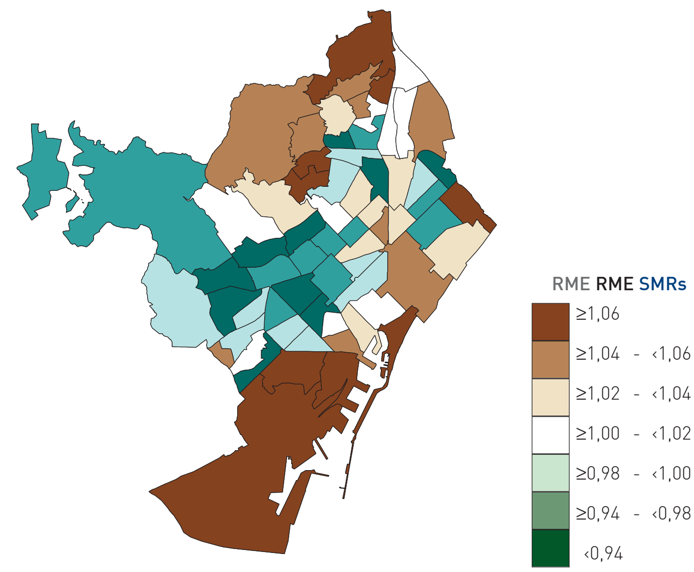

Densitat Densidad Density
3
2
1
0
0,4
0,8
1,2
1,6
2,0
RME RME SMRs


Àrees d'alt i baix risc
Áreas de alto y bajo riesgo
High-low risk areas
RME RME SMRs*
Màxim risc
Máximo riesgo
Highest risk
No significatiu
No significativo
Not significant
Mínim risc
Mínimo riesgo
Lowest risk
* Veure texte
* Ver texto
* See text

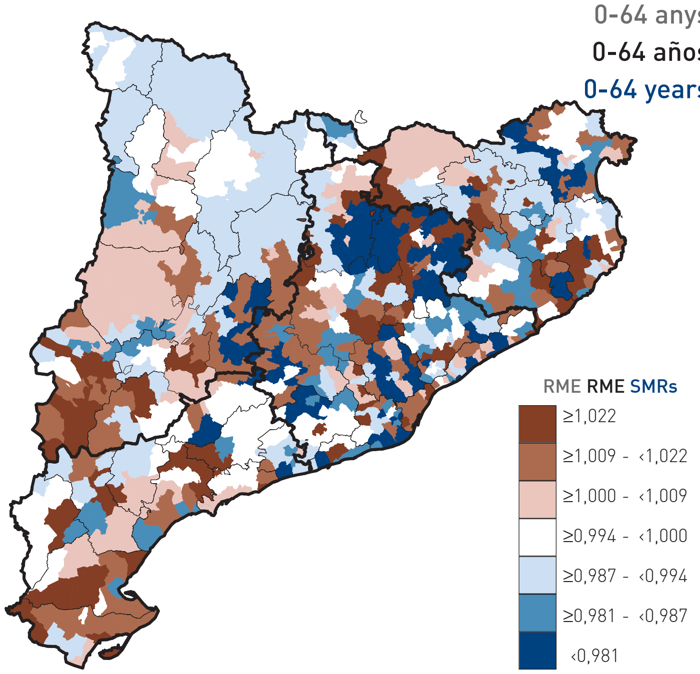
Àrees de Barcelona en comparació amb Catalunya
Áreas de Barcelona en comparación con Cataluña
Barcelona areas vs Catalonia



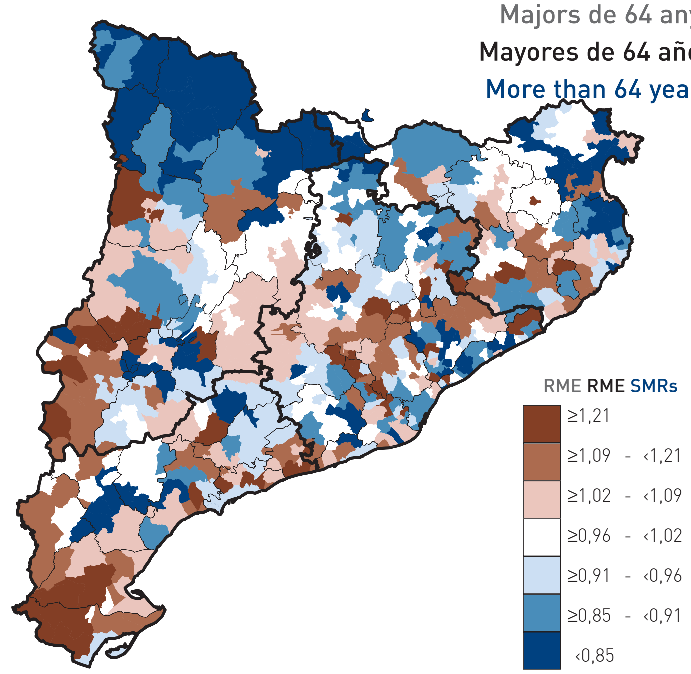
Àrees de Barcelona
Áreas de Barcelona
Barcelona areas



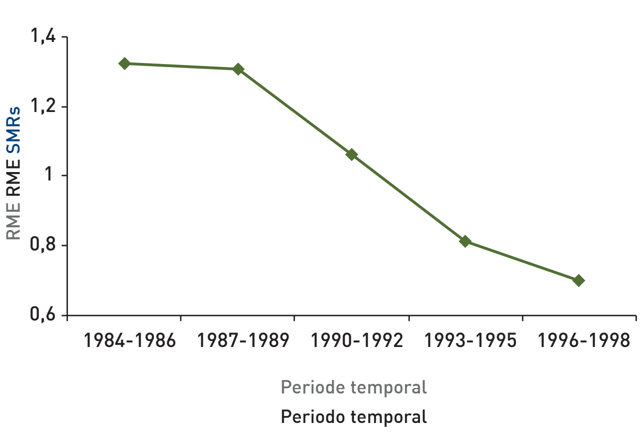
0-64 anys
0-64 años
0-64 years



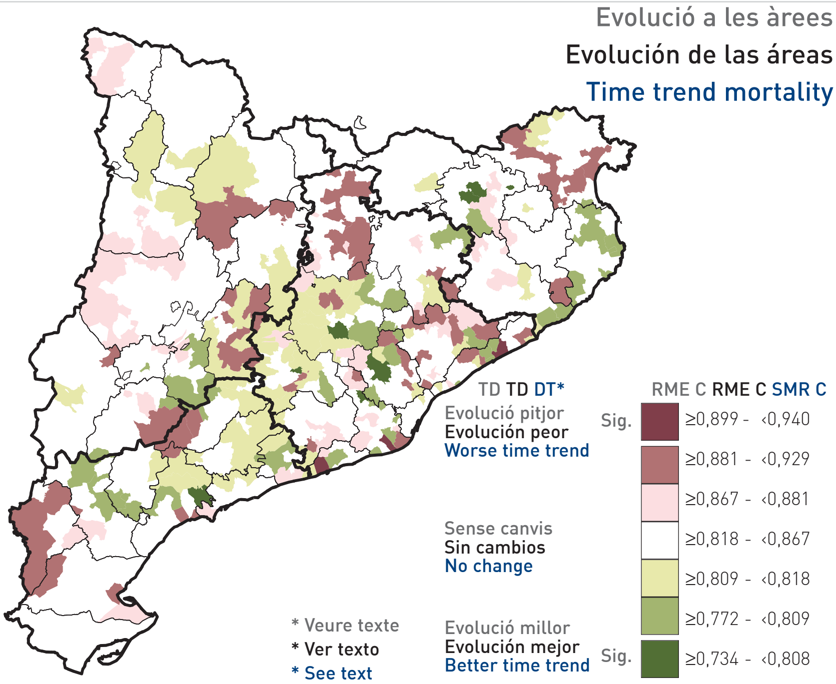
Majors de 64 anys
Mayores de 64 años
More than 64 years

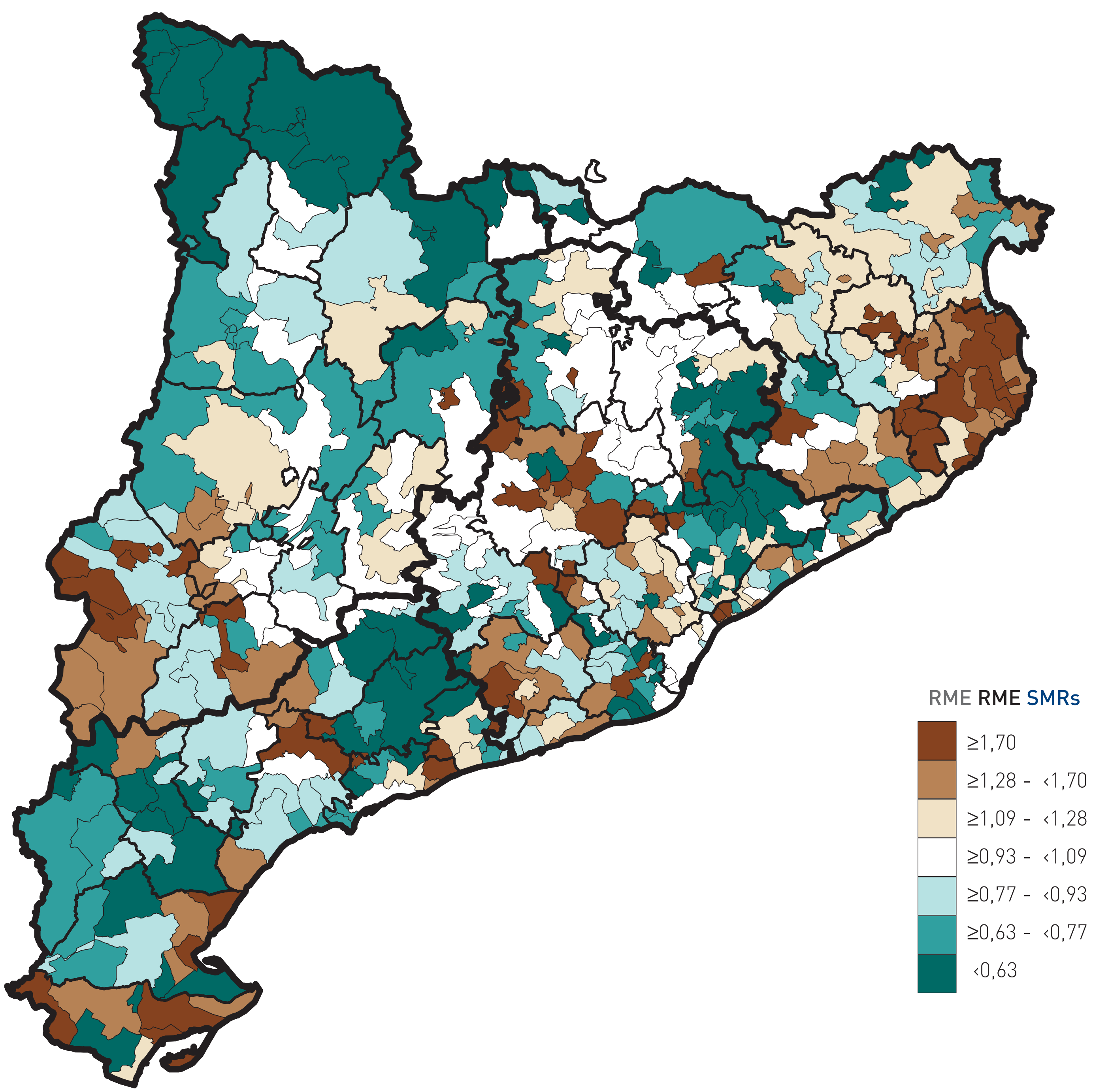


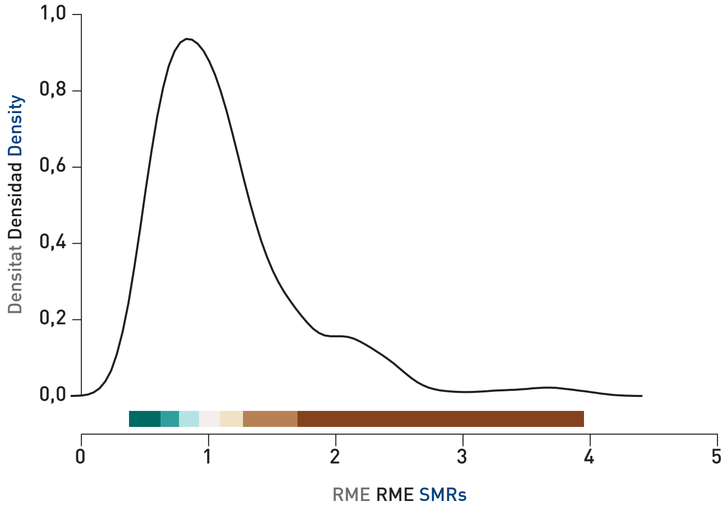
Evolució de la mortalitat a Catalunya (1984 -1998)
Evolución de la mortalidad en Cataluña (1984-1998)
Catalonia time trend mortality (1984-1998)

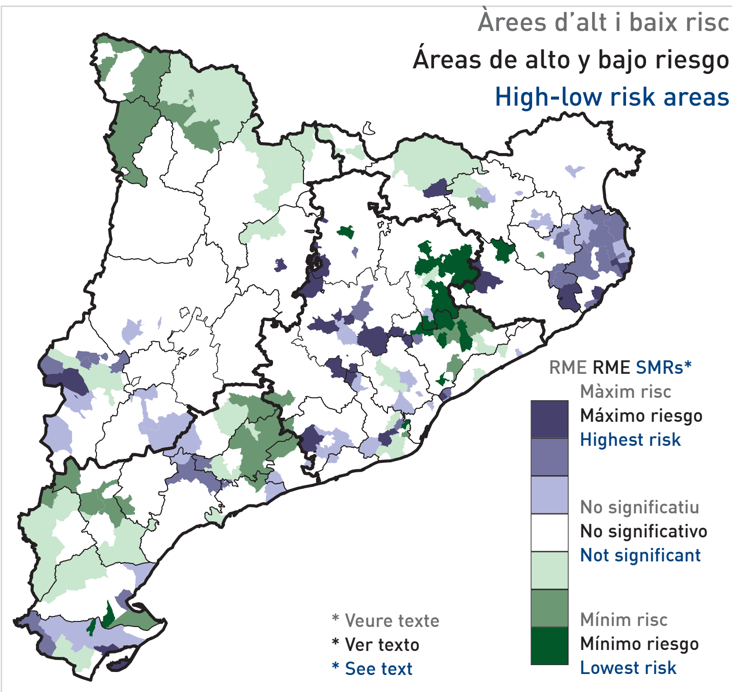


Evolució a les àrees
Evolución de las áreas
Time trend mortality



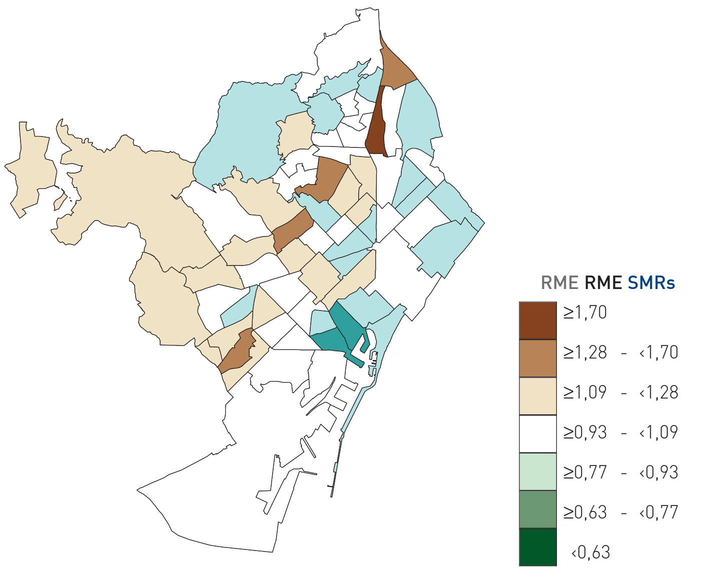

RME RME SMRs
≥1,70
≥1,28 - ‹1,70
≥1,09 - ‹1,28
≥0,93 - ‹1,09
≥0,77 - ‹0,93
≥0,63 - ‹0,77
‹0,63


1,0
0,8
0,6
0,4
0,2
0,0
Densitat Densidad Density
0
1
2
3
4
5
RME RME SMRs

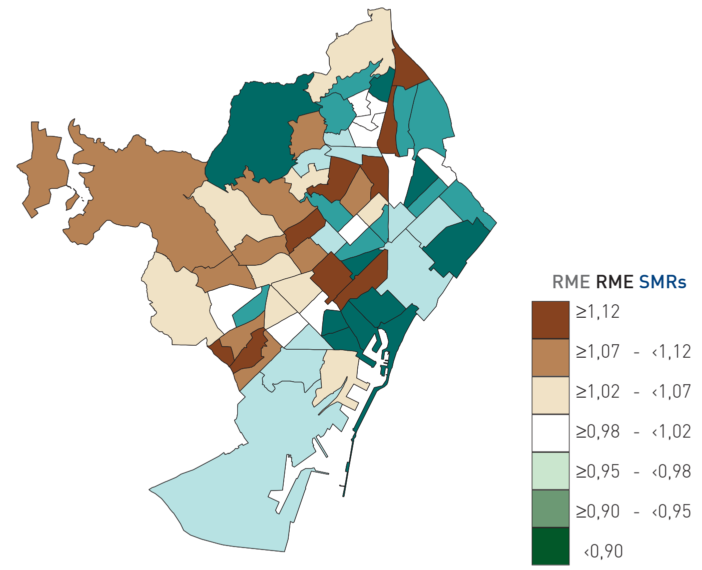

Àrees d'alt i baix risc
Áreas de alto y bajo riesgo
High-low risk areas
RME RME SMRs*
Màxim risc
Máximo riesgo
Highest risk
No significatiu
No significativo
Not significant
Mínim risc
Mínimo riesgo
Lowest risk
* Veure texte
* Ver texto
* See text

Raons de mortalitat estandarditzades (RME) — Aterosclerosi - Dones (CIM-9: 440)
Razones de mortalidad estandarizadas (RME) — Aterosclerosis - Mujeres (CIE-9: 440)
Standardised mortality ratios (SMRs) — Atherosclerosis - Women (ICD-9: 440)

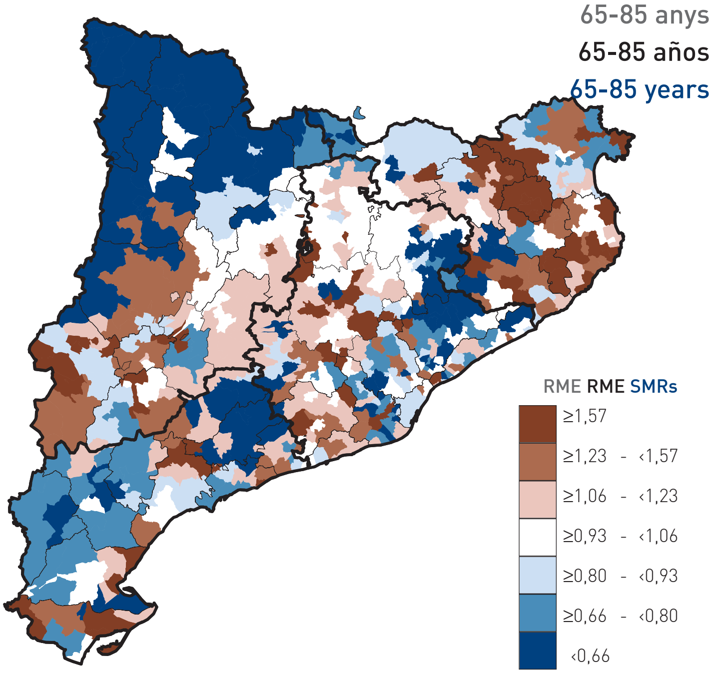
Àrees de Barcelona en comparació amb Catalunya
Áreas de Barcelona en comparación con Cataluña
Barcelona areas vs Catalonia



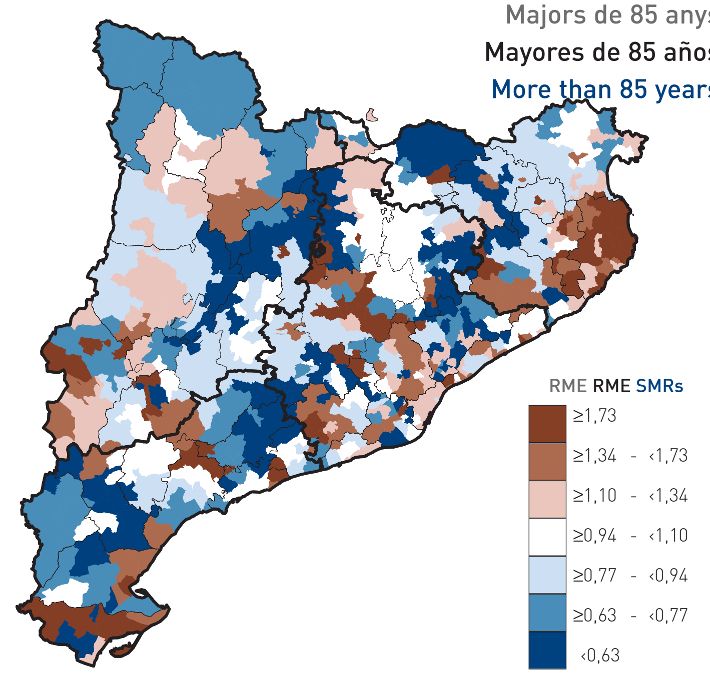
Àrees de Barcelona
Áreas de Barcelona
Barcelona areas



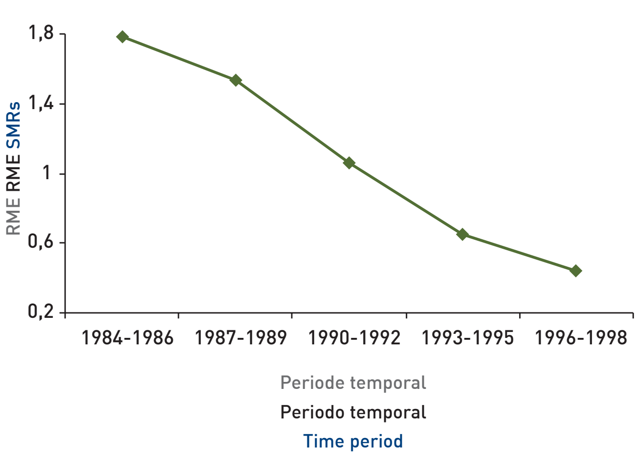
65-85 anys
65-85 años
65-85 years



Majors de 85 anys
Mayores de 85 años
More than 85 years



Evolució de la mortalitat a Catalunya (1984 -1998)
Evolución de la mortalidad en Cataluña (1984-1998)
Catalonia time trend mortality (1984-1998)



Evolució a les àrees
Evolución de las áreas
Time trend mortality