

An Atlas of Cancer in Ireland 1994-2003

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Summary

Background

Many of the causes of cancer are still not well understood. Although much is known about the effects of lifestyle and environmental factors, a considerable part of the cancer burden remains unexplained. Investigation of geographical differences in cancer incidence can throw light on both cancer aetiology and also on variations in cancer risk factors between populations. Spatial variation on a relatively fine scale may also yield information on the success of programmes of prevention, screening and early detection.

The aim of this report was to describe variations in cancer risk (incidence) at electoral district (ED) level in Ireland. The objectives were to:

- investigate geographical variation in cancer incidence in Ireland;
- examine the relationships between area-based characteristics (such as population density) and cancer risk;
- attempt to explain these relationships through the examination of area-based measures of socio-economic status and aspects of lifestyle.

Methods

The analyses were based on cancers diagnosed in the population of Ireland during 1994-2003, and registered with the National Cancer Registry. Each case was assigned to an electoral division (ED), based on the address of the patient at the time of diagnosis. The ED was used to allocate a value to each case, for a range of area-based measures of socio-economic status. Cases were assigned to a deprivation category, ranging from least (level 1) to most (level 5) deprived, based on the deprivation index developed by the Small Area Health Research Unit from various 2002 census socio-economic variables. A measure of the population density of each ED was created, based on the average number of inhabitants at the 1996 and 2002 censuses. EDs were combined into approximate tertiles for analysis (<1 person/hectare, 1-20 persons/hectare, >20 persons/hectare) and cases assigned to the appropriate tertile. EDs were also aggregated into quartiles of a range of socio-economic variables from the 2002 census: % unemployed, % agricultural workers, % lower social class, % manual workers, % non-manual workers, % early school leavers, % with no car, % local authority housing, % overcrowded housing and % of persons aged 65 and older living alone. Cases were assigned to the appropriate quartile for each variable. Population data was derived from the census Small Area Population Statistics (SAPS) files for 1996 and 2002.

In the spatial analysis, for each cancer site, an age-standardised incidence ratio (SIR) was computed for each ED. Bayesian conditional autoregressive models (CAR) were used to smooth these estimates. Models were fitted using the Gibbs Markov Chain Monte Carlo algorithm in WinBUGS. The smoothed risk estimates (relative risks, RRs) were mapped for each cancer site individually. For those cancers which affect both sexes, relative risks were mapped for both sexes combined. and for males and females separately.

Poisson regression was used to investigate the relationships between the risk of cancer and deprivation, population density and the other area-based socio-economic variables. In each analysis, the lowest quantile was taken as the reference group. Relative risks for deprivation were adjusted for population density; risks for density and other socio-economic variables which were significantly associated with cancer incidence were mutually adjusted.

Data from the SLÁN survey on various aspects of socio-economic status, diet and lifestyle (e.g. % low income, % current smokers, etc) was mapped at the level of rural districts and informally compared to the cancer incidence maps where relevant.

Results

Geographical variation

- **All malignant cancers (excluding non-melanoma skin cancer):** In both men and women, there were areas of higher incidence around Dublin and Cork and, for men, around some other urban centres. Incidence was also higher than average in a band running across the northeast and north midlands, from Dublin to Sligo.
- **Non-melanoma skin cancer:** The geographical distribution of non-melanoma skin cancer was similar in men and women but the variation was somewhat more pronounced for men. Areas of higher incidence were seen around the cities of Dublin, Cork, Galway and Waterford. Within Cork and Dublin, the areas of higher incidence were in the south and east of the cities, respectively. Outside the urban areas, regions of high incidence were observed in areas along the west coast of Donegal, Mayo, Clare, Kerry, west Cork (men) and also on the coast of Waterford (men).
- **Breast cancer:** There was relatively modest geographical variation in breast cancer incidence. The areas of highest incidence were around the major urban areas, with the exception of Limerick. There was a slightly increased incidence in west Cork, north Kerry, and a large area in the east Midlands. Within Dublin, incidence was higher in the south east than in the north and west.
- **Colorectal cancer:** There was evidence of moderate geographical variation in colorectal cancer incidence. Incidence was higher than average in two areas - one centred on Cork city but extending into the far southwest - and the other in the north and centre of the country, in a broad band from Dublin through the northeast to Donegal. The pattern was similar in both sexes although for women incidence was higher in the centre and the northwest.
- **Lung cancer:** In both sexes, there was an area of higher lung cancer incidence in Leinster, with the highest rates in Dublin, Kildare and Wicklow. A much smaller area of high incidence was centred on Cork city. For men, there were pockets of high incidence in the northwest, in Sligo, Leitrim and Donegal. Within Dublin and Cork, the areas of highest incidence coincided with the more deprived areas in the north and northwest, respectively.

- **Prostate cancer:** Prostate cancer incidence was highest around the major urban centres, with the exception of Limerick. Within Dublin, incidence was higher in the south of the city than in the north. There were also distinct areas of higher incidence in the northwest of the country, in Sligo and Donegal.
- **Stomach cancer:** Stomach cancer showed one of the strongest patterns of geographical clustering, with higher incidence in two clearly defined areas; one covering the northeast, stretching from Dublin through Louth, Monaghan and Cavan, and the other in south Donegal. Within Dublin, incidence was highest in the north and west of the city. The pattern was quite similar in both sexes.
- **Bladder cancer:** Geographical variation in bladder cancer was more marked in men than women. In men, there were three areas of higher incidence - along the east coast in Dublin and Wicklow, in Co. Donegal, and around Cork city. The pattern for women was less distinct, but there were again areas of higher incidence around Dublin (mainly confined to the city) and in Donegal, confined mainly to the Inishowen peninsula, and a trend of slightly increasing incidence heading towards the southwest.
- **Melanoma of the skin:** There were pronounced areas of higher incidence in west Cork, in, and to the north of, Dublin, in and around Cork and Waterford, and along the west coast of Donegal. Among men, there were also some patches of higher incidence in the west, on the coasts of Co. Galway and Co. Mayo. Within Dublin, incidence was highest in the south of the city.
- **Head and neck cancer:** For men, there were several patches of high incidence - in the main urban centres, in a band running from Cork to Galway, in a broad area in the north midlands, in northwest Mayo and in the Iveragh peninsula in Kerry. Within Cork and Dublin, head and neck cancer was more common in more deprived areas. In women, geographical variation was less marked. There was a region of higher incidence in and around Dublin and in the northeast, with a smaller area with higher rates in the northeast tip of Co. Donegal.
- **Oesophageal cancer:** Few areas had a particularly high incidence of oesophageal cancer. The country was split into areas of lower incidence in the northwest of the country (Galway, Clare, Sligo and Donegal counties) and those of slightly higher incidence in the northeast and running toward the south and west.
- **Cancer of the cervix uteri:** The areas of highest incidence of cervical cancer were concentrated in and around Dublin and in a broad band down the eastern side of the country from Dublin through Kildare and Wicklow to Wexford. There was another less concentrated band of higher incidence running through the middle of the country from north to south. Lower incidence was observed in the southwest, in counties Cork and Kerry, as well as in Donegal in the northwest.

Deprivation

All of the cancer sites analysed showed some association with deprivation, either an increase with increasing deprivation (all malignant cancers and colorectal, lung, stomach, bladder, head and neck, cervical and oesophageal cancer) or a decrease (breast, prostate and non-melanoma and melanoma skin cancers). In general, the relative risk estimates for the most, compared to the least, deprived were relatively modest, falling in the range 0.8-1.3. Stronger associations were seen for lung cancer in men (RR=1.72) and women (RR=1.56), head and neck cancer in men (RR=1.78), cervical cancer (RR=1.74), and melanoma (RR in both sexes 0.64-0.66).

Population density

With the exception of prostate cancer, all of the cancers considered in this report were significantly associated with population density. More densely populated areas (those with a population of >20 persons/hectare) consistently had a higher risk of cancer than those that were sparsely populated (<1 persons/hectare). Some of the observed associations were reasonably strong: relative risks were 1.4 or higher for cancers of the bladder (men, RR=1.39; women RR=1.40), stomach (men, RR=1.45; women, RR=1.49) and lung (men, RR=1.62; women, RR=1.84).

Other area-based measures of socio-economic status

With the exception of cervical cancer, the risk of all cancers analysed in this report was higher in areas with the highest proportion of elderly people living on their own. Although the risk estimates were less than 1.3, this association between this factor and almost every cancer was statistically significant.

Areas with a higher percentage of agricultural workers had a consistently lower risk of cancer. This was seen for all cancers with the exception of prostate cancer.

The observed relationships between the other area-based characteristics and cancer risk - such as percentages of lower social class, unemployed, living in overcrowded housing, and early school leavers - tended to mirror the associations with deprivation.

Discussion

There are geographical variations in the risk of cancer across Ireland. For some cancers these patterns are quite striking (e.g. lung cancer, cervical cancer, non-melanoma skin cancer, melanoma of the skin), while for others they are less marked (e.g. breast cancer). Although some similarities were apparent (e.g. between lung cancer and other smoking-related cancers, between non-melanoma cancer and melanoma of the skin, and between breast and prostate cancer), the observed geographical variations were, in the main, different for different cancers. Generally, for those cancers that affect both sexes, the geographical distribution was similar for men and women.

It must be kept in mind that these variations in risk do not mean that the spatial location itself causes cancer; rather they are likely to reflect socio-economic differences in the population, geographical differences in exposure to risk factors and, for some cancer sites, variations in access to, or uptake, of screening or other cancer services.

As regards deprivation, the observed associations between deprivation and cancer incidence in Ireland are generally consistent with those reported from other countries, using both area-based measures of deprivation and a range of other individual-level measures of socio-economic status (e.g. occupation, education, housing tenure, income). Socio-economic variations in several lifestyle risk factors for cancer (e.g. smoking) are well known, and these probably underlie the observed associations.

The associations between cancer incidence and population density are likely to be, in part, due to residual confounding by socio-economic status, at least for those cancers positively associated with deprivation. But this cannot be the entire explanation, and it is likely that there are urban/rural variations in exposure to cancer risk factors and in health behaviours, including health service access and utilisation.

The inverse associations between the percentage of agricultural workers and risk of several cancers are, most probably, a reflection of the relationship between cancer risk and population density.

The similar associations between cancer risk and (a) overall deprivation and (b) individual measures of socio-economic status, such as unemployment, was unsurprising since several of these individual factors are included in the composite deprivation index.

The consistent association with the proportion of elderly living alone is hard to interpret. It seems most likely that it either reflects differences in patterns of exposure to cancer risk factors in older people who live alone compared to those who live with others, or is a proxy for some other unmeasured cancer risk factor.

Conclusions

This report has revealed geographical and socio-economic variations in cancer risk in Ireland. These are likely to reflect differences in social, economic, cultural and environmental differences between subgroups of the population. Although risk factors for cancer are not all well-defined, nor modifiable (e.g. family history, genetic background), it is likely that many of the differences observed reflect a combination of variations in well-known risk factors (such as tobacco smoking, alcohol drinking, obesity, diet, sexual behaviour, etc.) and variations in participation in screening, health awareness and access to cancer services. Since these factors are potentially modifiable, there is considerable potential for reducing cancer incidence in Ireland and eliminating the disparities described in this report.

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We would also like to thank several other organisations and individuals for providing data included in the report. The Central Statistics Office provided the small area census population data and the information from which numbers of deaths from cancer was derived. The SLÁN research group (<http://www.slan06.ie/team.htm>) very kindly agreed to share their data and we are indebted to them for this, in particular Dr Dorothy Watson, Senior Research Officer at the Economic and Social Research Institute. The map of radon exposure was provided by the Radiological Protection Institute of Ireland. Dr Alan Kelly and colleagues, from the Small Area Health Research Unit, Trinity College Dublin, created the deprivation index which was used in this report.

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1 Introduction

1.1 Background

Cancer is now the most common cause of death in Ireland (Central Statistics Office Ireland, 2009). Overall cancer incidence is expected to increase by 45% between 2010 and 2020, and by 110% between 2010 and 2030 (National Cancer Registry, 2008), mainly due to population ageing. Cancer mortality is also projected to increase (National Cancer Registry, 2003) although not to the same extent.

Many of the causes of cancer are still not well understood. Although much is known about the effects of lifestyle and environmental factors (see, for example, World Cancer Research Fund / American Institute for Cancer Research 2007, Boyle and Levin, 2008), a considerable part of the cancer burden remains unexplained. Investigation of geographical differences in cancer incidence can throw light on both cancer aetiology and also on variations in cancer risk factors between populations. Spatial variation on a relatively fine scale may also yield information on the success of programmes of prevention, screening and early detection. In many countries, including Ireland, where information on personal characteristics of cancer patients is not available to cancer registries for legal reasons, information at small area level can act as a proxy for individual-level data, and can give valuable information on the role of diet, lifestyle, and socio-economic factors, on the cancer burden. Such data can also highlight disparities or variations in access to cancer services at all levels.

1.2 Aim of the report

Worldwide variation in cancer incidence has been extensively studied, most comprehensively in the quinquennial reports "Cancer Incidence in Five Continents" (Curado et al, 2007), produced by the International Agency for Research on Cancer, and publications based on this data (see, for instance, Bray et al, 2004, Bray et al, 2005, Devesa et al, 2005). Part of this variation is due to genetics, and the past few years have seen major advances in the understanding of the genetic and molecular basis of the disease. However, the majority of the variation is a result of social, economic, cultural and environmental differences between populations and describing variations in cancer rates between countries has served to provide clues to specific aetiological factors involved.

Variations in cancer risk and aetiological factors between countries are often large and readily amenable to study, but the study of the much smaller range of geographical variation within countries is more challenging. However, it also has the potential to provide insights which are of local significance. Although current cancer patterns reflect past patterns of exposure to risk factors, taking steps now to deal with these factors in the population has the potential to bring about reductions in future cancer incidence and mortality. Sometimes, merely drawing attention to variation can influence behaviour at both official and individual level to reduce cancer risk. Geographical variation in cancer incidence and mortality and survival (Kogevinas et al, 1997, Coleman et al, 1999) has been closely linked to patterns of socio-economic status and deprivation. Identification of these patterns can draw attention to the wider dimensions of health which need to be addressed in order to reduce cancer morbidity and mortality.

The aim of this report was to describe variations in cancer risk (incidence) at electoral district level in Ireland, with a view to identifying remediable risk factors. The objectives of the report were to:

- investigate geographical variation in cancer incidence in Ireland;
- examine the relationships between geographically-based characteristics (such as population density) and cancer risk;
- attempt to explain these relationships through the examination of area-based measures of socio-economic status and aspects of lifestyle.

1.3 Content of the report

This report brings together - for the first time - detailed descriptions of geographical variations in cancer risk in Ireland, with census data on characteristics of local areas and survey data on lifestyle factors. Cancer incidence rates across the country have been mapped using sophisticated methods of spatial analysis. The available data on risk factors has also been mapped, and statistical analysis has been used to explore links between the area characteristics and cancer risk.

Chapter 2 describes the data included in the report, and the methods of analysis. Chapter 3 includes results of the analysis for all malignant cancers, and chapters 4 to 14 include results for 11 of the most common cancer sites - namely non-melanoma skin, colorectal, breast, prostate, lung, stomach, bladder, head and neck and oesophageal cancer, cancer of the cervix uteri, and malignant melanoma of the skin. Chapter 15 contains incidence maps for six additional cancers (lymphoma, leukaemia and cancers of the pancreas, ovary, corpus uteri and brain and central nervous system (CNS)); these are presented in summary form because either the annual incidence was considered to be too low to justify full analysis, or there was little in the way of a geographical pattern. Maps showing the geographical distribution of selected cancer risk factors are included in Appendix 1. Appendix 2 contains summary tables from analyses of area characteristics (e.g. deprivation, population density) and cancer risk. Appendix 3 includes summary statistics related to the maps of cancer incidence. A map showing county boundaries in Ireland is provided in Appendix 4.

2 Methods

2.1 Data sources

2.1.1 Cancer registrations

The analyses in this report are based on cancers diagnosed in the population of Ireland during 1994-2003, and registered with the National Cancer Registry. Since 1st January 1994, all newly diagnosed cancers in Ireland have been registered by the National Cancer Registry. The process is highly effective, with over 96% of cancers being identified (National Cancer Registry, 2001). Prior to 1994, there was no national cancer registration and therefore no reliable information available on cancer incidence.

A summary of the cancers included in this report is given in table 2.1. Those tumours defined as “multiple primary cancers” according to international guidelines (Ferlay et al, 2005) were identified, and only a single instance of each cancer has been counted. When several primary malignant tumours occurred in the same site, only the first occurrence was considered. Cancer registration is a dynamic process and registrations may be added, changed or removed from the database over time as new information comes to light, sometimes several years after the original diagnosis. This means that the numbers of cancers in this report may differ slightly from those published elsewhere.

Table 2.1 Incident cancers diagnosed 1994-2003 and included in this report

Cancer site	ICD 10 codes	Total no. of cases, 1994-2003		Annual average no. of cases, 1994-2003	
		<i>females</i>	<i>males</i>	<i>females</i>	<i>males</i>
all malignant cancers	C00-C96	87,299	94,657	8,730	9,466
all malignant cancers, excl C44 ¹	C00-C96, excl C44	64,002	68,519	6,400	6,852
non-melanoma skin	C44	23,297	26,138	2,330	2,615
breast	C50	18,196	128 ²	1,820	13 ²
colorectal	C18-C21	7,873	10,321	787	1,032
lung	C34	5,846	10,246	585	1,025
prostate	C61	-	15,252	-	1,525
lymphoma	C81-C85	2,433	2,853	243	285
stomach	C16	1,830	2,920	183	292
bladder	C67	1,320	3,312	132	331
melanoma of the skin	C43	2,659	1,624	266	162
leukaemia	C91-C95	1,602	2,292	160	229
head and neck	C01-C14, C30-C32	1,010	2,759	101	276
pancreas	C25	1,800	1,787	180	179
ovary	C56	3,454	-	345	-
brain and other central nervous system	C70-C72	1,450	1,835	145	183
kidney	C64	1,101	1,966	110	197
oesophagus	C15	1,205	1,861	120	186
corpus uteri	C54	2,332	-	233	-
cervix uteri	C53	1,834	-	183	-

¹ excludes non-melanoma skin cancer; ² since breast cancer in males is rare, the analyses in chapter 5 are limited to breast cancer in females

2.1.2 Geocoding cancer cases to electoral divisions

The address of each cancer patient at the time of diagnosis is recorded by the Registry. The county of residence can be easily determined in the majority of cases from the address given. However, for detailed geographical analysis, each case must be assigned to an area much smaller than a county. In this way, areas of high cancer incidence can be more precisely defined and information on cancer incidence can be linked to known characteristics of an area, such as population density and deprivation (see below). The smallest useful area for this purpose in Ireland is the electoral division (ED) - formerly known as a district electoral division - as this is the smallest area for which census data can be obtained. These areas have a mean population of around 1,000 people, but can be much larger, and will typically be quite heterogeneous in population compared to, for instance, census enumeration districts in the UK (Coleman et al, 2001).

In theory, each cancer patient can be assigned to an ED, using the address given to the hospital at the time of diagnosis; this process is known as geocoding. However, in Ireland, addresses are not unique and have no postcodes, so they must be assigned to an ED by matching the address given to those in a database of all known addresses and their associated EDs. Three databases of this kind are available in Ireland - GeoDirectory, from An Post/OSI; address tables from the quinquennial censuses from the Central Statistics Office (CSO); and the electoral registers. All of these databases have limitations. None can be completely up-to-date, although the GeoDirectory is updated four times a year. GeoDirectory, in general, holds only one address, the official postal address, for each building, so alternative addresses, which are quite common in rural Ireland, are often not listed. The census tables are quite incomplete, and many addresses are not registered. The electoral registers were the most comprehensive listing of addresses, and tended to use addresses in everyday use rather than the postal address. However, with the passing of the Electoral (Amendment) Act, 2001, access to the full register was ended and the edited register now available is of much less value for geocoding. Using a combination of these three databases, it should be theoretically possible to match the addresses of all cancer patients to EDs. In practice, however, many addresses available to the Registry are incomplete, non-standard or inaccurate. In addition, none of the available databases lists every address and some have errors. At best, only 70% to 80% of addresses have a close match in any of the databases, and the remaining 20-30% have to be matched manually by inspection of individual records, with reference to large-scale maps. As the Registry records over 20,000 new cases each year, assigning an ED to each case is a time-consuming process.

As part of an ongoing geocoding project, the cancer cases included in this analysis were assigned to EDs using probabilistic matching software developed by the Registry specifically for this purpose. Addresses were also matched independently to the GeoDirectory database and to the electoral register for the same period. Addresses which could not be assigned to one specific ED by this process were individually inspected by Registry staff and, by referring to the GeoDirectory and the electoral registers, all but a small number could be allocated to an ED. For those registrations where a single ED could not be definitely assigned (3.9% of all malignant cancers; table 2.2), a number of alternative EDs were assigned. In calculating incidence rates for each ED (see below), a fraction of the cases was allocated to each of the alternative EDs. At the end of the process, a number of registrations remained which could not be assigned to any ED (4.6% of all malignant cancers; table 2.3). These registrations were excluded from the analyses in this report. This loss was taken into account in the calculation of the incidence rates (see below 2.1.3.1)

Apart from its obvious use in allocating cancer cases to specific areas and studying geographical patterns, geocoding provides a "key", allowing cancer cases to be linked to other area-based data, such as measures of socio-economic status (e.g. deprivation indices (Small Area Health Research Unit (SAHRU), 1997), percentage unemployed, etc) or population density. This is described in more detail below. This type of information is not, in general, accessible at the level of the individual cancer case in Ireland, and has to be inferred from area-based measures.

Table 2.2 Outcome of process of assigning cancer cases to EDs: cases not assigned to an ED and cases assigned to multiple EDs

Cancer site	Cases not assigned to an ED		Cases assigned to more than one ED		
	No. of cases	% of cases	No. of cases	% of cases	No. of EDs
all malignant cancers	8,422	4.6%	7,112	3.9%	2,279
all malignant cancers excl C44 ¹	5,839	4.4%	5,091	3.8%	2,005
non-melanoma skin	2,580	5.2%	2,022	4.1%	1,608
breast	699	3.8%	640	3.5%	795
colorectal	755	4.1%	759	4.2%	912
lung	700	4.4%	514	3.2%	717
prostate	725	4.8%	622	4.1%	811
lymphoma	266	5.0%	187	3.5%	321
stomach	226	4.8%	201	4.2%	348
bladder	169	3.6%	179	3.9%	303
melanoma of the skin	231	5.4%	143	3.3%	270
leukaemia	181	4.6%	164	4.2%	296
head and neck	142	3.8%	139	3.7%	246
pancreas	165	4.6%	154	4.2%	285
ovary	157	4.5%	130	3.8%	225
brain and other CNS	161	4.9%	122	3.7%	231
kidney	143	4.7%	126	4.1%	227
oesophagus	141	4.6%	140	4.6%	243
corpus uteri	85	3.6%	69	2.9%	135
cervix uteri	74	4.0%	58	3.2%	100

¹ excludes non-melanoma skin cancer

2.1.3 Characteristics of EDs: population and socio-economic variables

2.1.3.1 Population

The 2002 census provided population data, broken down by age and sex, for 3,422 EDs in Ireland. These had an average population of 1,145; ranging from 55 (Branchfield, Co. Sligo) to 24,404 (Blanchardstown-Blakestown,

Table 2.3 Confidential electoral divisions - 2002

County	Confidential ED		ED combined with		New ED			
	No.	Name	No. of persons (2002)	No.	Name	No. of persons (2002)	Name	No. of persons (2002)
Laoighis	046	Capard	47	045	Brisha	224	Brisha/Capard	271
Longford	035	Newgrove	37	024	Firry	172	Firry/Newgrove	209
Offaly	034	Ballaghassaan	34	043	Esker	350	Esker/Ballaghassaan	384
Clare	017	Ballyeighter	46	020	Glenroe	117	Glenroe/Ballyeighter	163
Clare	133	Inishcaltra South	41	132	Inishcaltra North	276	Inishcaltra North/ Inishcaltra South	317
Cork	046	Whiddy	29	033	Bantry Rural	952	Bantry Rural/Whiddy	981
Tipperary North	045	Lackagh	20	037	Greenhall	237	Greenhall/Lackagh	257
Waterford City	006	Ballynaneashagh	17	002	Ballybeg South	265	Ballybeg South/ Ballynaneashagh	282
Waterford	074	Kilbarry (part)	45	070	Ballynakill (part)	327	Ballynakill (part)/Kilbarry (part)	372
Galway	027	Derrycunlagh	47	022	Bencorr	201	Bencorr/Derrycunlagh	248
Galway	126	Loughatorick	34	129	Marblehill	363	Marblehill/Loughatorick	397
Leitrim	034	Arigna	15	041	Garvagh	119	Garvagh/Arigna	134
Leitrim	029	Aghavoghill	40	027	Aghalateeve	94	Aghalateeve/Aghavoghill	134
Mayo	065	Sheskin	25	058	Glenco	100	Glenco/Sheskin	125
Mayo	130	Bundorragha	97	150	Owennadornaun	96	Owennadornaun/Bundorragha	193
Sligo	027	Mullagheruse	49	031	Templeboy South	194	Templeboy South/Mullagheruse	243
Cavan	082	Derrynananta	39	084	Dunmakeever	130	Dunmakeever/Derrynananta	169
Cavan	087	Teebane	34	086	Killinagh	110	Killinagh/Teebane	144
Cavan	028	Tircahan	32	025	Pedara Vohers	154	Pedara Vohers/Tircahan	186

Co. Dublin). The population of a number of EDs was so low that the CSO considered these EDs "confidential", only published total population figures for them, and amalgamated them with one or more neighbouring EDs. EDs were considered confidential if they included either 15 households or less or 50 persons or less. There were 19 such confidential EDs in 2002 and these are shown in table 2.3.

Population data was derived from the census Small Area Population Statistics (SAPS) files for 1996 and 2002. SAPS populations from the 1996 census were used as the denominators for cases incident in 1994-1996. Data from the 2002 census was used for cases incident in 2002 and 2003, and a linear interpolation of the 1996 and 2002 census counts was used for cases incident in 1997-2001.

The definition of a small number of EDs, and therefore the associated SAPS data, changed between the 1996 and 2002 censuses. These changes consisted of splitting or amalgamation of areas, rather than any movement of boundaries. EDs which had changed in this way were combined for analysis, and the available age and sex distribution similarly combined (table 2.4). This combining of areas gave a final total of 3,419 EDs.

Table 2.4 Combined EDs with boundary changes between 1996 and 2002 censuses

ED number	Geographical area	ED name	SAPS data 1996 ¹	Published total figure 1996 ²	SAPS data 2002 ¹	Published total figure 2002 ²
19003	Co 18 Cork County	Tralee U.D.	19,056	6,085	6,311	6,311
19165	Co 19 Kerry	Tralee Rural (part)	860	12,971	15,433	14,064
		Tralee Rural (part)		860		1,369
33003	Co 32 Cavan	Letterkenny U.D.	7,606	2,473	2,478	2,478
33105	Co 33 Donegal	Letterkenny Rural (part)	2,341	5,133	9,289	5,487
		Letterkenny Rural (part)		2,341		3,802
34004	Co 33 Donegal	Monaghan U.D.	5,628	2,014	2,032	2,032
34063	Co 34 Monaghan	Monaghan Rural (part)	1,207	3,614	4,969	3,685
		Monaghan Rural (part)		1,207		1,284

¹ source: SAPS files where population data is available by age group and sex; ² source: Central Statistics Office, 2003

2.1.3.2 Population density

As the formal definition of "urban" areas in Ireland does not include many areas at the periphery of towns and cities, urban and rural populations were distinguished by population density (table 2.5), based on the average number of inhabitants at the 1996 and 2002 census. Three categories were created for analysis, with the cut-off points (<1 person/hectare, 1-20 persons/hectare, >20 persons/hectare) chosen to give an approximately equal population in each group.

Table 2.5 Distribution of cancer cases in 1994-2003,¹ 2002 population and number of EDs, by population density tertiles

Population density	No. of cancer cases ¹	2002 population	No. of EDs
<1 person/ha	50,794	1,546,928	2,726
1-20 persons/ha	28,983	1,127,965	277
>20 person/ha	43,009	1,242,310	416

¹ all malignant cancers, excluding non-melanoma skin cancer

2.1.3.3 Socio-economic indicators

Socio-economic information for each ED was based on data from the 2002 census, which was more detailed than that contained in the 1996 census and also covered a small number of additional EDs not in the 1996 SAPS. The available variables are listed in table 1.5 and relate to: unemployment, employment type and social class, housing, car ownership, school leaving age, and elderly persons living alone. The socio-economic variables were highly correlated in time. For example, areas with high unemployment in 2002 also had high unemployment in 1996 (correlation coefficient=0.83). Similarly, the composite deprivation index (see below) was also correlated between 1996 and 2002 (correlation coefficient=0.77). The same was true when census data for 1991 were considered. This means that the choice of year should make little difference to the results. In the analysis, these socio-economic indicators (other than the composite deprivation index - see below) were categorised into quartiles based on population.

Table 2.6 Socio-economic indicators available at ED level in the 2002 census

Variable	Definition
unemployment	Proportion of the economically active population aged over 15 unemployed or seeking a first job
agricultural workers	Proportion of persons from socio-economic groups I (farmers) and J (agricultural workers)
manual workers	Proportion of persons in socio-economic groups E (manual skilled), F (semi-skilled) and G (unskilled)
non-manual/higher professional workers	Proportion of persons from socio-economic groups A (employers and managers), B (higher professional), C (lower professional) and D (non-manual)
lower social class	Proportion of persons classified as 5 to 6 on the Irish Social Class Scale ¹
early school leavers	Proportion of persons whose education ceased at, or before, age 15
overcrowded housing	Ratio of the total number of persons divided by the total number of rooms in permanent private households, therefore representing the average number of persons per room
local authority housing	Proportion of houses purchased from local authority or rented from local authority
car ownership	Proportion of persons who do not own a car
65 and older living alone	Proportion of those aged 65 and older who live alone

¹ O'Hare et al, 1991

2.1.3.4 Deprivation

The deprivation index developed by Dr Alan Kelly of the Small Area Health Research Unit was used as an index of relative deprivation at the ED level (Kelly and Teljeur, 2004). It is similar in design to the widely regarded Carstairs and Townsend indices employed in the UK (Carstairs and Morris, 1991, Phillimore et al, 1994), with certain modifications in view of differences in definition and scope between census variables in the UK and Ireland. The index is a combination of several socio-economic variables from the 2002 census, namely unemployment, social class, type of housing tenure, car ownership and overcrowding. A score was determined for each ED based on the first principal component from principal component analysis. The score was divided into quantiles, ranging from least to most deprived. Although approximate deprivation deciles are available, to provide more stable estimates the ten categories were collapsed into five, with two deciles assigned to each approximate quintile (table 2.7).

Table 2.7 Population and number of EDs included in the each deprivation category

Deprivation category	2002 population	no. of EDs	% of total population
1 (Least deprived)	926,000	684	23.6%
2	593,197	684	15.1%
3	546,843	685	14.0%
4	685,703	684	17.5%
5 (Most deprived)	1,165,460	684	29.8%

2.1.3.5 Correlations between deprivation index, population density and socio-economic variables

Table 2.8 shows the correlation coefficients between the deprivation index, population density and various individual census-based socio-economic variables. Several of the variables were highly correlated. As might be expected, population density was strongly inversely associated with the proportion of agricultural workers. The individual variables which make up the composite deprivation index were, unsurprisingly, strongly positively correlated with the overall index. There were positive correlations between the proportions of early school leavers and those classified as lower social class, the proportions unemployed and those living in local authority housing, and the proportions in local authority housing and those without a car. The percentage of elderly people living alone was not strongly correlated with any of the other variables.

2.1.3.6 Geographic distribution of deprivation index, population density and socio-economic variables

Map 2.1 shows the geographical distribution of the deprivation index. EDs which fall into the highest deprivation category are concentrated in parts of Dublin and Cork and towards the west and northwest of the country. Population density tertiles are shown in map 2.2. Only EDs in the very centre of the largest towns and cities fall into the highest tertile of population density (416 EDs; table 2.5). In most of the country, the population density is less than one person per hectare; 2,226 EDs are included in the lowest population tertile.

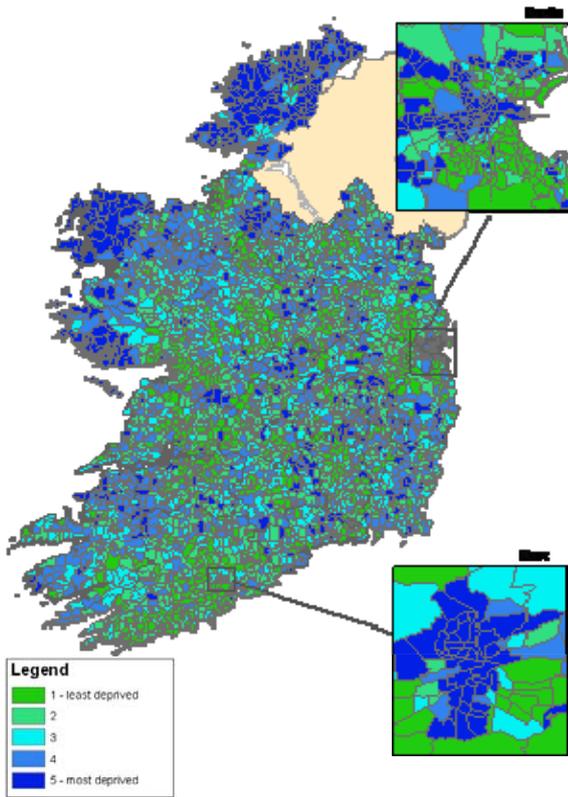
Maps 2.3-2.12 show the geographical distribution of the other census-based socio-economic variables. These were divided into 10 groups using natural breaks defined using the ArcGis function which identifies break points and maximises differences between groups (Environmental Systems Research Institute Inc., 2007). The colour ramp goes from green to blue, with areas with the lowest proportion of the variable (group 1) shown in dark green, areas with the highest proportion of the variable (group 10) shown in dark blue, and areas with intermediate values (groups 2-9) shown in a range of shades ranging from lighter green to lighter blue.

Table 2.8 Matrix of correlation coefficients for ED characteristics

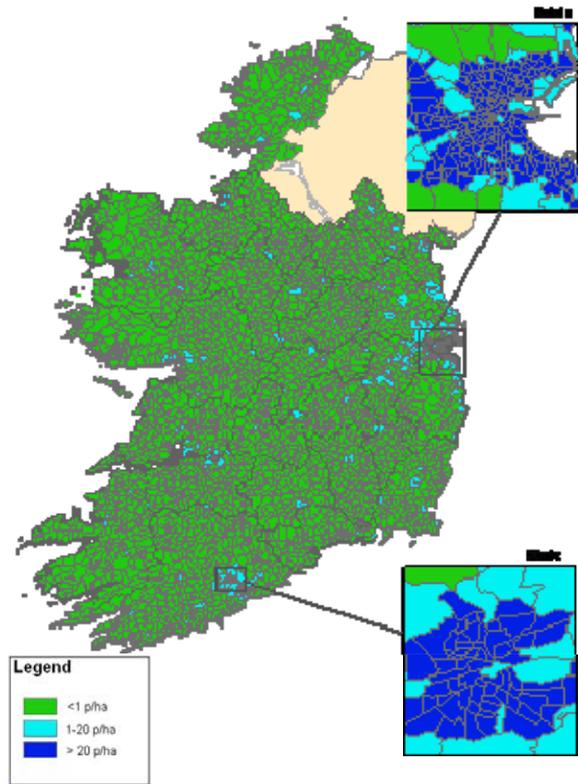
	deprivation index	population density	unemployment	lower social class	early school leaver	no car	overcrowded housing	local authority housing	% 65+ living alone	agricultural workers	non-manual worker
deprivation index	1										
population density	0.176	1									
unemployment	0.762	0.233	1								
lower social class	0.732	-0.099	0.471	1							
early school leaver	0.427	-0.275	0.265	0.531	1						
no car	0.629	0.476	0.513	0.369	0.208	1					
overcrowded housing	0.453	-0.067	0.247	0.303	0.270	0.008	1				
local authority housing	0.712	0.287	0.525	0.452	0.202	0.528	0.249	1			
% 65+ living alone	0.198	0.0002	0.143	0.175	0.167	0.357	-0.125	0.151	1		
% agricultural workers	-0.168	-0.892	-0.248	0.118	0.356	-0.443	0.069	-0.302	0.038	1	
% non-manual workers	-0.403	0.403	-0.205	-0.589	-0.676	-0.119	-0.301	-0.162	-0.157	-0.499	1
% manual workers	0.553	-0.060	0.347	0.650	0.421	0.215	0.351	0.399	0.099	0.042	-0.417

Red font=correlation >0.5; green font= correlation in range 0.4-0.5

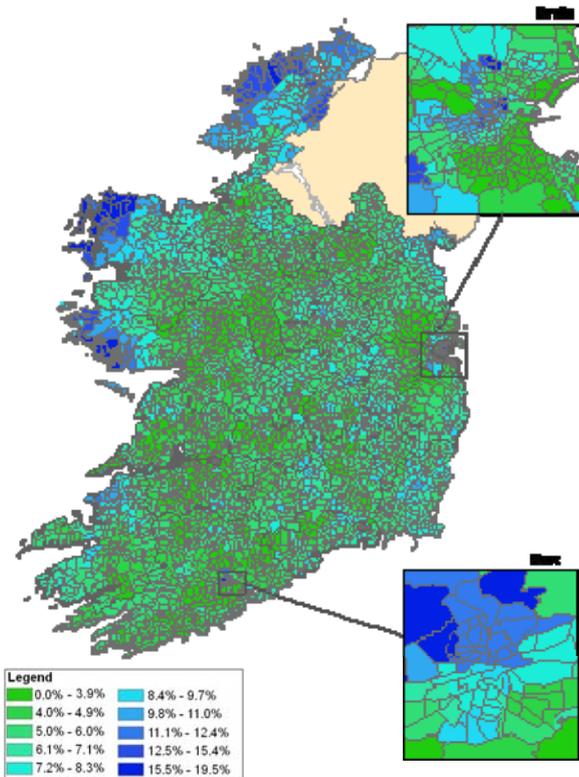
Map 2.1 Deprivation index



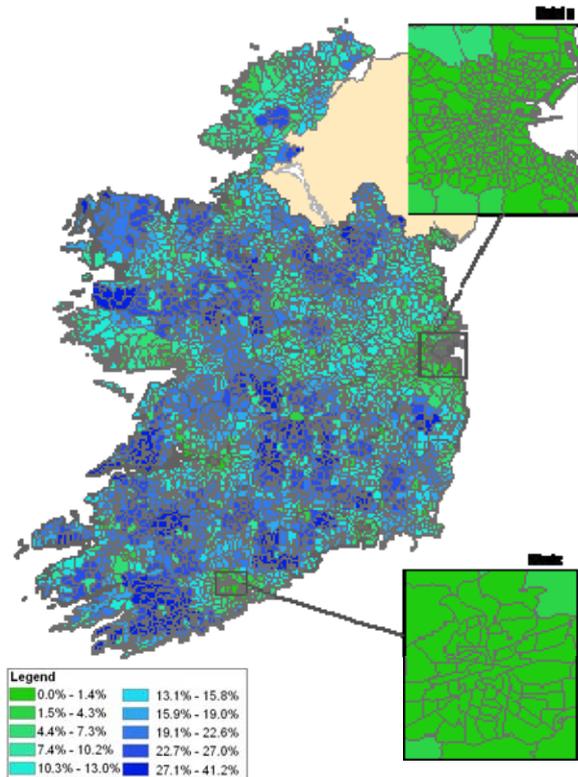
Map 2.2 Population density



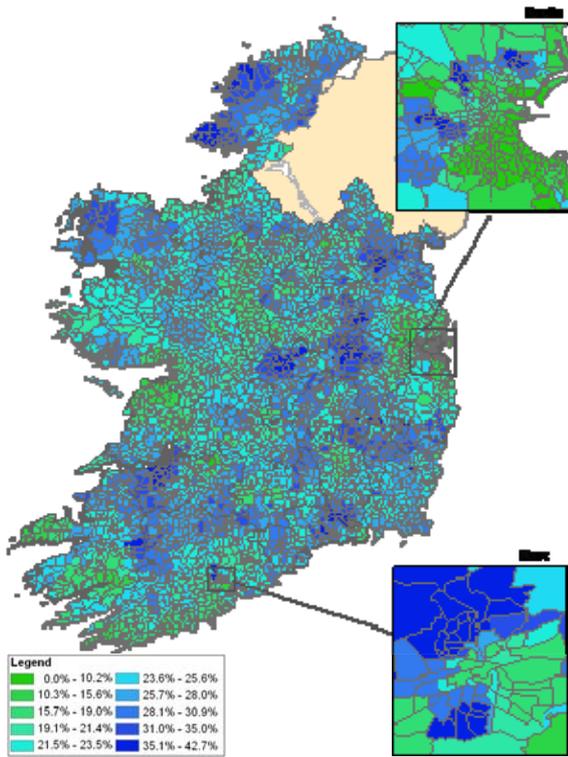
Map 2.3 Percentage unemployed



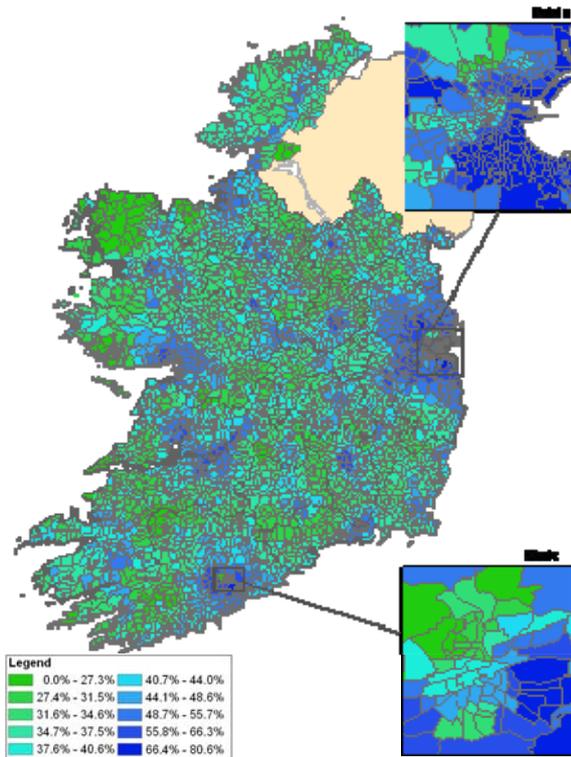
Map 2.4 Percentage of agricultural workers



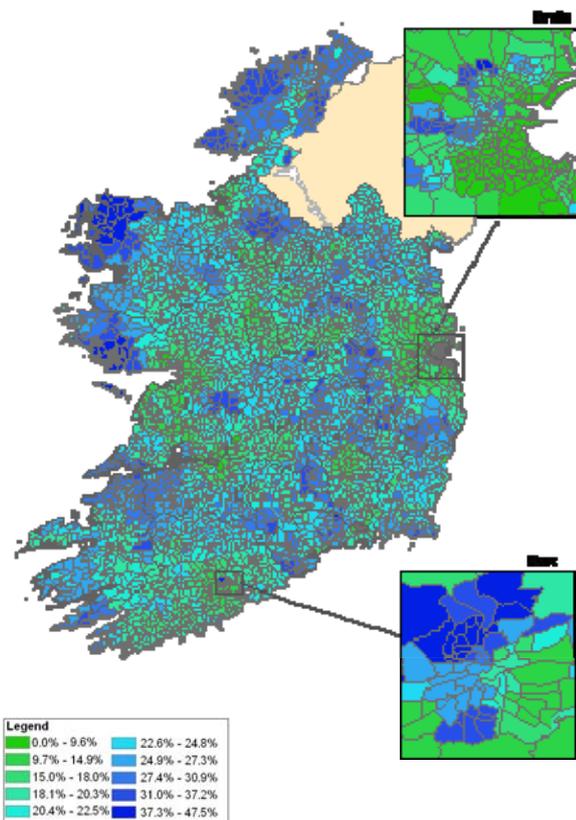
Map 2.5 Percentage of manual workers



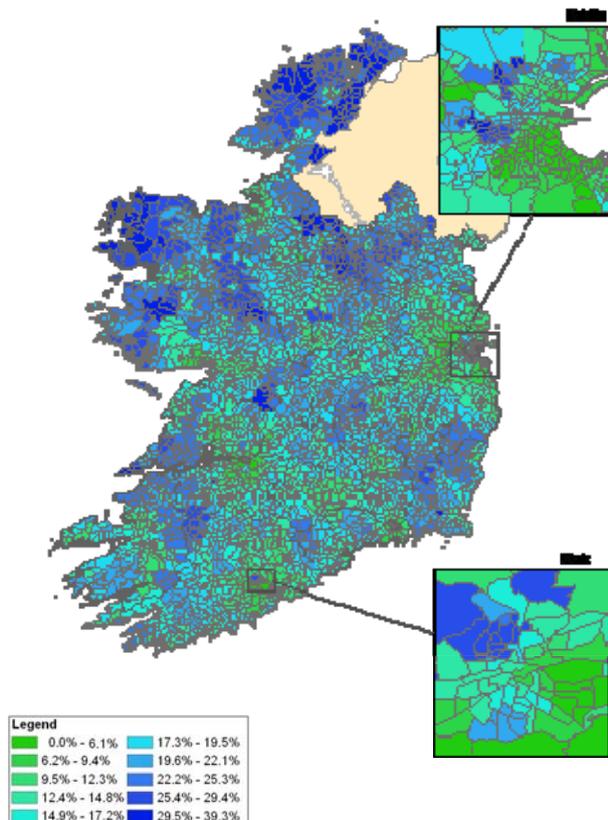
Map 2.6 Percentage of non-manual workers



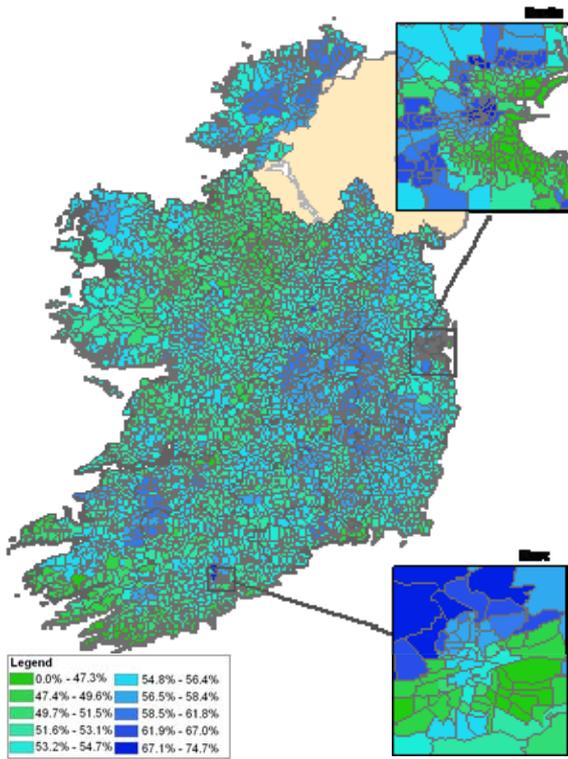
Map 2.7 Percentage in social classes 5 & 6



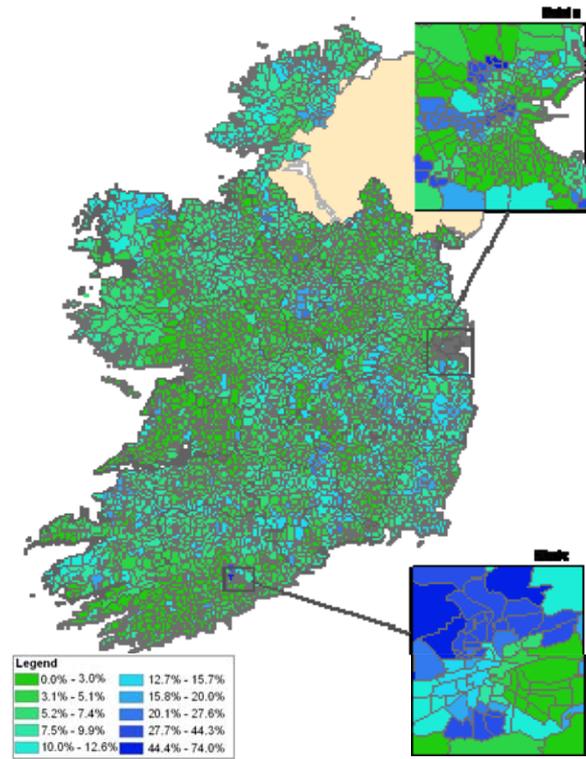
Map 2.8 Percentage of early school leavers



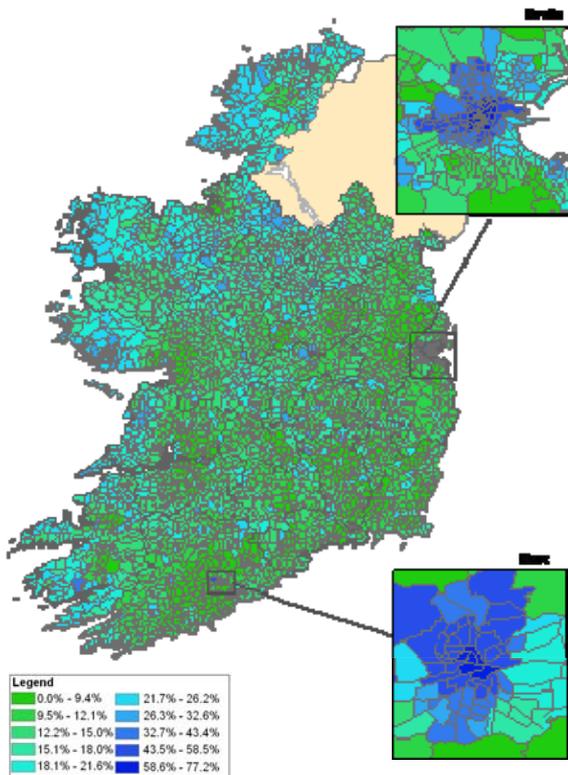
Map 2.9 Percentage in overcrowded housing



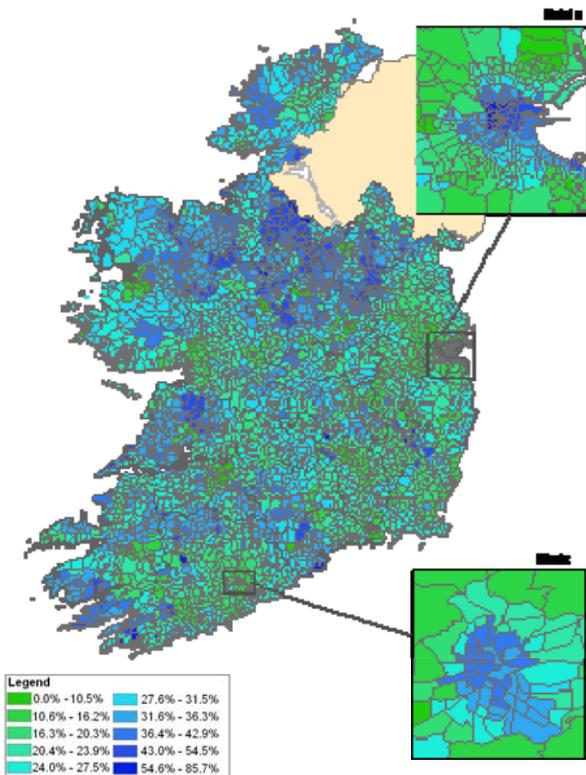
Map 2.10 Percentage in local authority housing



Map 2.11 Percentage without a car



Map 2.12 Percentage aged 65 and older living alone



2.1.4 Exposure data

The authors of the SLÁN survey (Morgan et al, 2008) provided information on various aspects of socio-economic status, diet and lifestyle. This data was collected in a population survey, conducted in 2007, which involved face-to-face interviews with more than 10,000 adults across Ireland. Although available at ED level, the information was aggregated into larger geographical areas to avoid identifying respondents. The information provided was expressed as the percentage of respondents in each geographical area, and related to the following variables:

- % in social class 6
- % in quintile five (highest) of household equivalised income
- % below 60% of median equivalised income (modified OECD equivalence scale)
- % covered by private health insurance
- % who are obese (self-reported body mass index $\geq 30\text{kg/m}^2$)
- % with low fruit and vegetable intake (fewer than five helpings of fruit and vegetables daily)
- % with low fibre intake (less than 25g fibre daily)
- % with high intake of red and processed meat ($>300\text{g}$ red and processed meat per week)
- % with heavy alcohol consumption (≥ 14 units weekly)
- % who currently smoke (daily or occasionally).

As the data was sparse, and perhaps unrepresentative at the ED level, it was not formally incorporated into the analyses in this report. Instead it is used in a purely descriptive way to add some context to the disease mapping, and to aid interpretation of the geographical patterns in disease incidence. The authors of the current report mapped the data; these maps are shown in Appendix 1.

Also shown in Appendix 1 is a map of predicted radon exposure in Ireland, derived from a report by the Radiological Protection Institute of Ireland (Fennell et al, 2002).

2.1.5 International cancer incidence data

Estimates of cancer incidence in Europe and the United States of America are taken from the GLOBOCAN 2002 software package (Ferlay et al, 2004). These estimates are sometimes quite different from the actual incidence rates given in this report for 1994-2003, for two reasons: the projections of 1999 incidence rates on which they are based may not always be accurate and they are standardised to the World, rather than the European, Standard population. However, they are useful in giving a general idea of the incidence of cancer in Ireland relative to other countries.

2.2 Statistical analysis

2.2.1 Standardised incidence ratio

In comparing cancer cases between areas or over time, two important factors must be considered - the number of people at risk and their ages. The reason and method for correcting for the number of people at risk is obvious - the number of cases is divided by the number of people resident in the area during a specified period, as reported by the census, to produce an incidence rate (or mortality rate if deaths rather than cases are being considered).

Since the risk of developing cancer risk doubles with every eight or nine years of life, an area with an older population would be expected, all else being equal, to have more incident cancer cases than an area with a younger population. There are several different approaches available to correct for age. We have used indirect standardization. This is the most appropriate method for small area comparisons, as it provides more stable rates than other standardization techniques, and works even if there is no population-at-risk in some age groups within the area (Estève et al, 1994). For each small area i , we apply the national incidence rates for each age group j to the population counts (N) in each age group, to calculate the total expected (E) number of cancers in the area. This can be compared to the number actually found in the area, in the form of an observed (O) to expected ratio, or percentage. This is called the standardised incidence ratio, abbreviated to SIR. The SIR for any cancer for Ireland as a whole is, by definition, 1 (or 100%).

$$SIR_i = \frac{O_i}{E_i} \text{ where, } E_i = \sum_j N_{ij} \frac{O_j}{N_j}$$

2.2.2 Spatial analysis and smoothing

There are several types of geographical analysis of disease incidence:

- disease mapping, which aims to provide an estimate of the disease rate in each small area which is as close as possible to the true value;
- cluster studies, which specifically search for “clusters” - areas or groups of areas where risk is significantly higher than in the rest of the population;
- point source studies, which investigate disease risk around a "point source" of possible risk which has been defined *a priori* (e.g. an industrial site).

Because our primary aim was to estimate risks precisely in each small area (ED), we used disease mapping methodology.

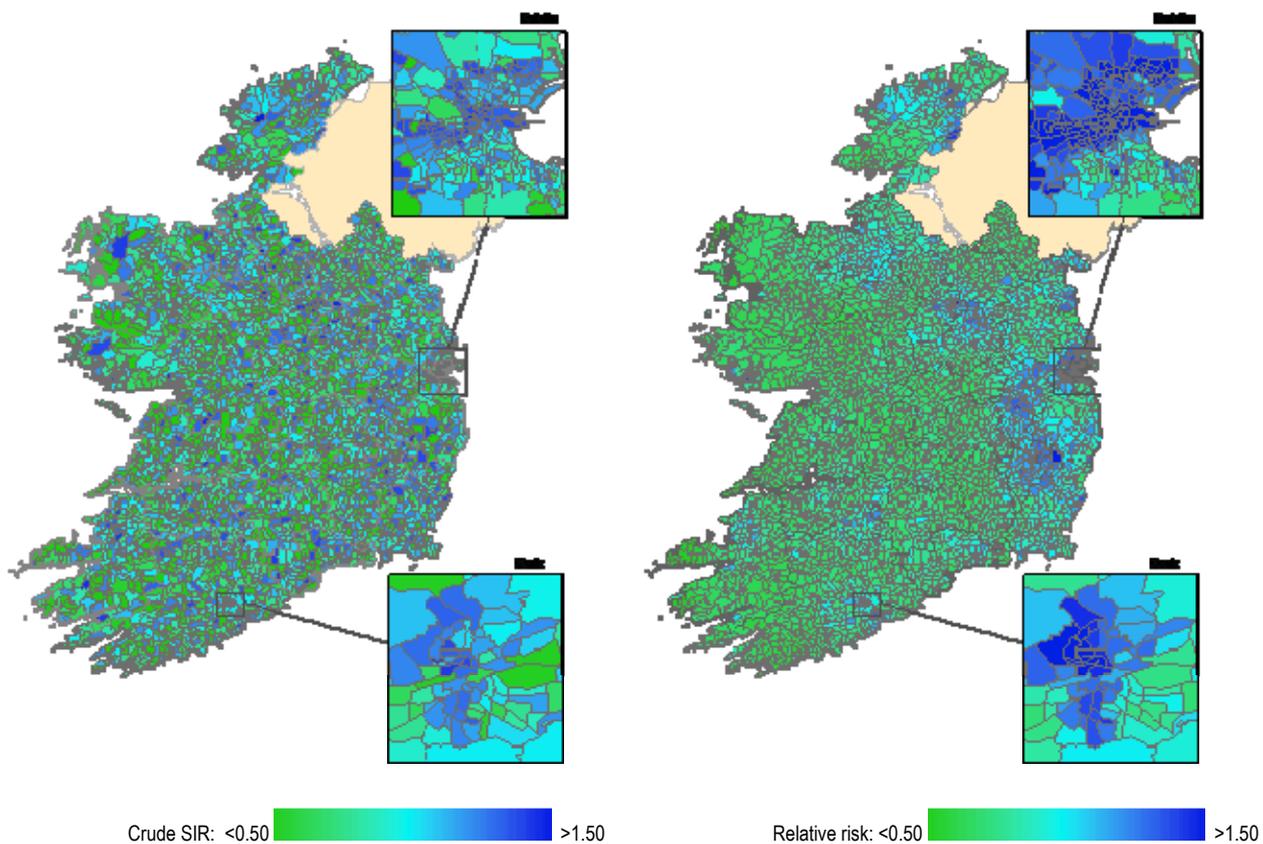
Incidence rates, whether crude or standardised, are subject to high variability due to the small number of cases incident in each small area, and the often small population-at-risk. In many instances, areas with small populations can appear to have a particularly high or low risk, purely by chance. The average population of an ED in Ireland is about 1,145, but some are considerably smaller. One of the commonest cancers, colorectal cancer, has an incidence rate of 0.5 cases per 1,000 persons per year, so even over the 10-year period examined here, only 5 cases would be expected in a typical ED. With such small numbers, random variation is the major factor in the variation of incidence rates between EDs, and this “noise” tends to obscure any other patterns. Therefore, simply mapping the SIRs for each ED can be seriously misleading, as the SIRs tend to be more extreme in areas where the population is sparse. These areas are often the largest in area and can dominate a map visually. This is illustrated for lung cancer in map 2.13.

The way of dealing with this problem involves "smoothing" the estimates of disease risk (Elliott et al, 1992). Smoothing removes the noise (i.e. it smoothes out the random variation) and shows the true geographical pattern in risk more clearly. This produces relative risks (RR). The effect of smoothing is illustrated in map 2.14, which shows smoothed RRs for lung cancer, compared with the unsmoothed SIR in map 2.13.

The section below describes, in statistical terms, how the smoothed RRs were estimated. The principle of spatial smoothing is straightforward. If we assume that the risk of cancer does not vary much between areas which are close to each other, then differences between EDs are more likely to be due to random variation than to real differences in risk. The smaller the population of the area, the larger will be the element of random variation and the crude SIR will be quite an unreliable indicator of real risk. Smoothing the SIR for an ED allows us to strengthen the estimate for the ED by “borrowing strength” from adjacent areas (local smoothing) and/or from the overall/national map (global smoothing) in order to increase the stability of the estimated RR. Therefore, what smoothing does is to adjust risk estimates based on small numbers towards a local mean - based on the rates in the neighbouring areas - and also towards the national value (1.0).

Map 2.13 Lung cancer, crude SIRs: both sexes, 1994-2003

Map 2.14 Lung cancer, smoothed RRs: both sexes, 1994-2003



Many methods have been proposed for smoothing disease rates (Elliott et al, 1992). We have chosen to use a Bayesian approach (Best et al, 2005). The main advantage of Bayesian techniques is that they work well in situations of limited information and high uncertainty. They are better at accurately depicting the geographical pattern in risk than other techniques, such as non-hierarchical approaches, which are more likely to be visually misleading (Pasutto et al, 2000).

The SIRs were smoothed by estimating relative risks using conditional autoregressive models (CAR) (Clayton and Kaldor, 1987) based on a spatial Poisson model with two random effects, as follows:

$$O_i \sim \text{Poisson}(E_i \theta_i)$$

$$\log(\theta_i) = \alpha + h_i + b_i$$

where

O_i is the observed number of cancer cases in area i ;

E_i is the expected number based on national incidence rates;

b_i is a spatially structured random effect (which is given a CAR prior distribution);

h_i is a random effect which models the unstructured heterogeneity;

α is the intercept; and

θ_i is the estimated relative risk.

Use of CAR models is widespread in disease mapping and this particular model is known to be appropriate in most situations (Lawson et al, 2000, Best et al, 2005). Other methods (e.g. kernel smoothers, mixture models) seem to give poorer results than CAR (Lawson et al, 2000). Although risk estimates can be somewhat underestimated, CAR models have a high specificity (Richardson et al, 2004), and this conservative approach means that high or low estimates are more likely to be real. However, with this method, as with any smoothing method, it is possible that areas of genuinely high risk may be missed by smoothing with neighbouring areas. The method also assumes that risk varies smoothly at the scale studied, an assumption which may not be justified if environmental effects at a purely local level (e.g. air pollution) are important.

We fitted our models using Markov Chain Monte Carlo (MCMC) algorithms with WinBUGS software (Lunn et al, 2000). Estimates were checked to ensure convergence had been reached. A burn-in of 50,000 iterations (or more if convergence was not reached) was performed for each model and the posterior distributions were derived using one in three iterations from the subsequent 10,000 iterations.

Relative risks (RR) were mapped for each cancer site individually using ArcMap 9.2. For those cancers which affect both sexes, maps are included for the sexes combined and for males and females separately. County boundaries are shown faintly on the maps to help the reader with geographical orientation; a map of the counties is contained in Appendix 4. To facilitate comparisons between cancer sites, each map is shown using the same colour ramp, which goes from dark green for an estimated RR less than 0.50 to dark blue for a RR higher than 1.50 (i.e. the same colour represents the same value of RR on each map). Appendix 3 contains summary information from the mapping of each cancer site, including average numbers of cases per ED, and mean crude SIR and smoothed RRs.

2.2.3 Poisson regression: ED characteristics and cancer incidence

We used Poisson regression to investigate the relationship between the risk of cancer and deprivation, population density and other area-based socio-economic variables. The number of new cancer cases in ED i , age group j , is assumed to be Poisson distributed. Fitting the model produces an estimate of the risk of cancer for each quantile

of the explanatory/independent variable(s), relative to a common reference category (e.g. quartile with lowest unemployment) - that is, it produces a RR.

The analysis proceeded as follows for each cancer site separately. The first analysis related to deprivation index. The least deprived quintile (deprivation group 1) was taken as the reference category and relative risks were computed for areas in deprivation categories 2-5. The risk estimates were adjusted for population density, since this is an important confounder of the relationship between deprivation and cancer incidence (see maps 2.1 and 2.2). In the second analysis, we built multivariate models using population density and the other variables shown in table 2.5 as candidate explanatory variables. Since some of the variables were highly correlated (table 2.6), their inclusion in the same model was not appropriate. To deal with this, we first created a multivariate model where all of the variables, except those relating to occupational group, were considered for inclusion (i.e. population density, unemployment, lower social class, overcrowded housing, local authority housing, car ownership and 65 and older living alone). We retained in the final models those variables which provided the best fit to the data, as assessed by likelihood ratio tests and the Akaike information criterion (AIC). We then built a model exploring the relationship between occupational group (percentages of agricultural workers, manual workers and non-manual workers) and cancer. These models included the same adjustment factors as the previous multivariate model, except that population density was not included (since population density and percentage of agricultural workers was so highly correlated). We presented results for the occupational group with the best model fit. For those cancers which affect both sexes, the models were created using data for both males and females. The results of these analyses are contained in the individual chapters relating to each cancer site. In addition, Appendix 2 includes summary tables which provide an overview of the results.

Using Poisson regression to model relative risk based on small-area has limitations. In particular, there may be overdispersion, which occurs when the observed variance is higher than expected (Breslow, 1984). This is because Poisson models do not have a dispersion parameter and the geographical distribution of the data makes it likely that dispersion will be high. In practice, the relative risks will be correctly estimated but the confidence intervals may be under-estimated.

3 All malignant cancers¹

3.1 Summary

Each year approximately 6,400 men and 6,852 women are diagnosed with cancer in Ireland (table 3.1). These figures exclude cases of non-melanoma skin cancer, which are presented in chapter 4. During the period 1993-2003, the annual incidence rate of all malignant neoplasia rose by 1.19% in men and 1.12% in women.

Table 3.1 Summary information for all malignant cancers (excluding non-melanoma skin cancer) in Ireland, 1994-2003

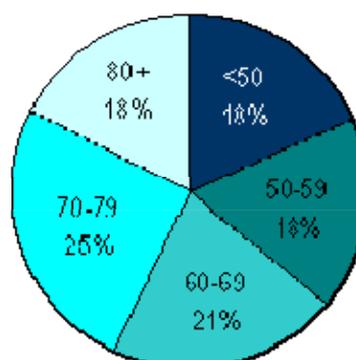
	females	males
% of all new cancer cases	100%	100%
Average number of new cases per year	6,400	6,852
Average number of deaths per year	3,481	4,008
Age standardised incidence rate per 100,000 (European standard population)	338	422
Estimated annual percentage change in rate 1994-2003	1.12%	1.19%

The incidence of cancer increases with age (figure 3.1). The age distribution was different for males and females. 18% of cases in females, but only 10% in men, were aged under 50 at diagnosis, while one third of cases in men, and only one quarter of cases in women, were diagnosed between aged 70-79.

Figure 3.1 Age distribution of all malignant cancer cases, 1994-2003, males and females

males

females

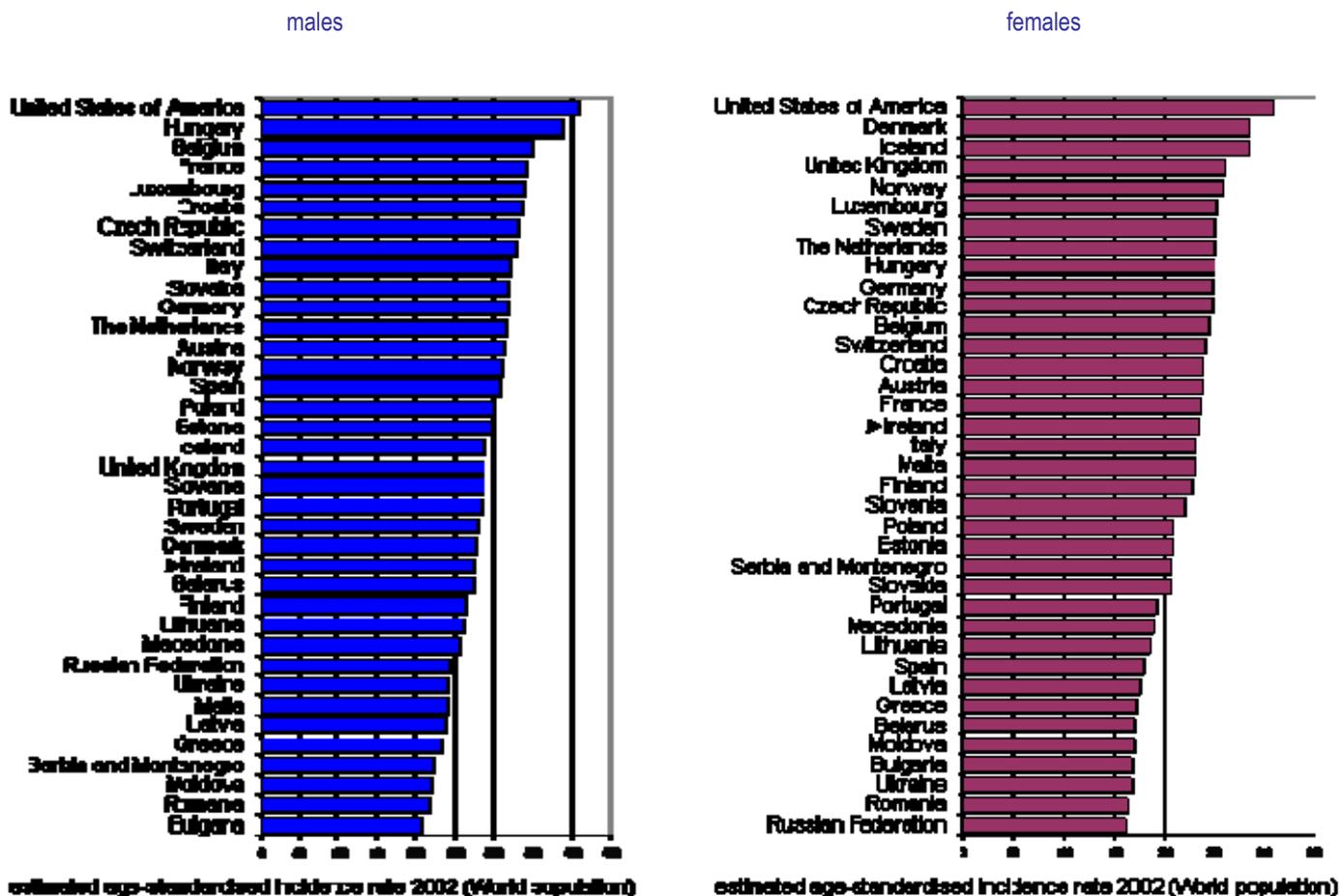


¹ The figures in this chapter exclude non-melanoma skin cancer.

3.2 International variations in incidence

Cancer incidence in men in Ireland is in the lower half of incidence rates across Europe (figure 3.1) and below most other western European countries. For females, the incidence rates are just above the median.

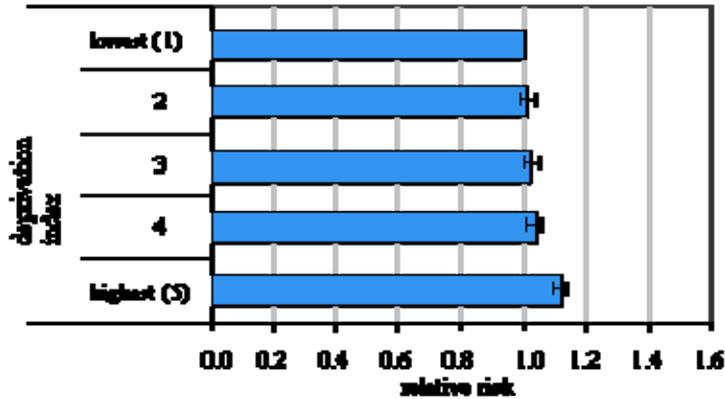
Figure 3.2 Estimated incidence rate per 100,000 in 2002 for Europe and USA: all malignant cancers, excluding non-melanoma skin cancer



Source: GLOBOCAN 2002 (Ferlay et al, 2004)

3.3 Electoral district characteristics and cancer incidence

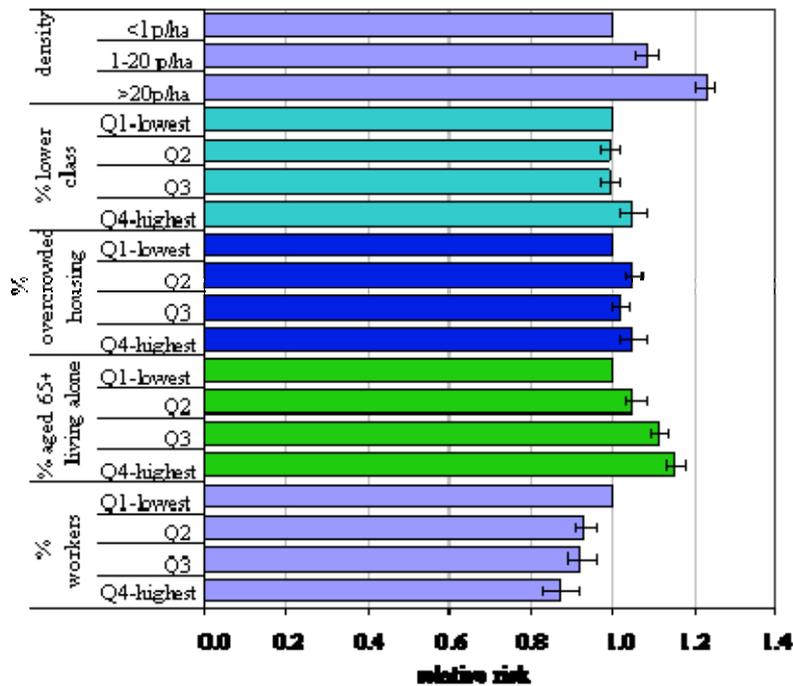
Figure 3.3 Adjusted relative risks of cancer by deprivation index: males



In men, overall cancer incidence was significantly associated with the deprivation index of the area of residence. There was a modest trend of increasing risk with increasing deprivation. The risk of cancer was 12% higher in the most, compared to the least, deprived areas (RR=1.12, 95% CI 1.09-1.14).

Adjusted for population density

Figure 3.4 Adjusted relative risks by area characteristics: males



Population density was strongly associated with cancer incidence in men. The risk of cancer was 23% higher in the highest density (>20 persons/hectare) compared to the lowest density (<1 p/ha) areas.

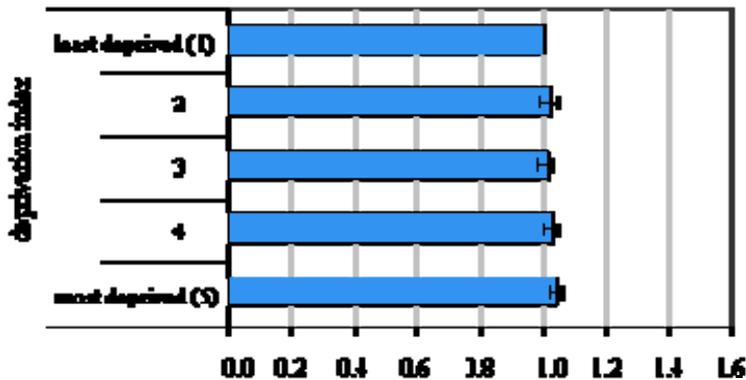
Areas with the highest proportion of persons in social class 5 of 6, and those with the most overcrowded housing, had a slightly higher risk of cancer in men, compared to areas with the lowest proportions of these factors.

Areas with the highest percentage of persons aged over 65 living alone had higher cancer incidence in men compared to areas with the lowest percentage.

Areas with a higher proportion of agricultural workers had a lower cancer incidence.

All variables mutually adjusted except % of agricultural workers (not adjusted for density)

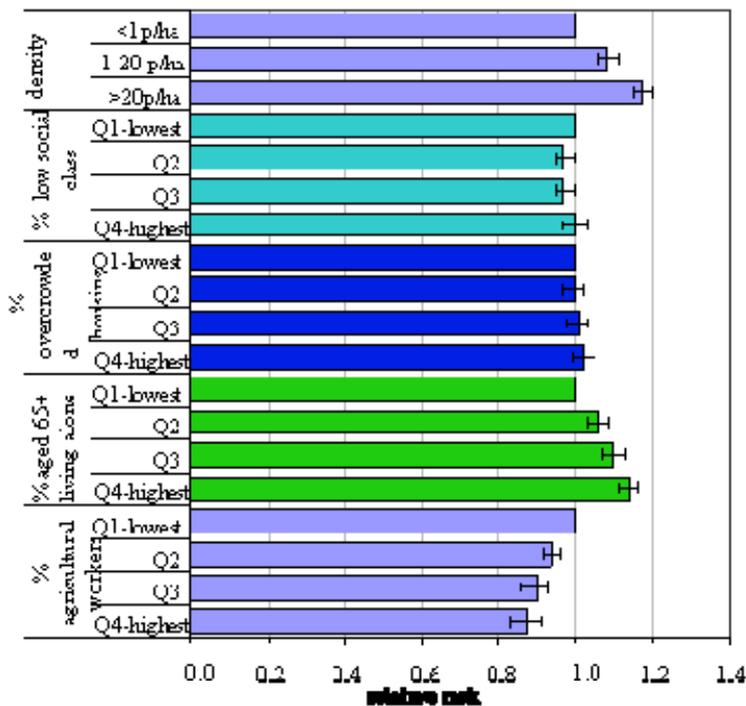
Figure 3.4 Adjusted relative risks of cancer by deprivation index: females



As with men, cancer incidence in women increased with increasing deprivation, but the trend was modest and the relative risk in the most deprived, compared to the least deprived areas, was lower than for men (RR=1.04, 95% CI 1.02-1.06).

Adjusted for population density

Figure 3.5 Adjusted relative risks of cancer by area characteristics: females



Increased population density was also associated with higher cancer incidence in women. Urban areas (density >20 p/ha) had a 17% greater incidence of cancer than the most rural areas (density <1 p/ha). This is also illustrated by the lower cancer incidence in areas with the highest proportion of agricultural workers.

Unlike for men, lower social class and overcrowded housing were not significantly associated with risk of cancer in women.

Areas with the highest percentage of people over 65 living alone had the highest incidence of cancer in women.

All variables mutually adjusted except % of agricultural workers (not adjusted for density)

Socio-economic variation

The strongest associations with increased cancer incidence at area level were higher population density and the proportion of people aged 65 and older living alone. For males, and to a lesser extent females, deprivation was also associated with risk. For men also, the percentage of residents in lower social classes and the proportion in overcrowded housing were associated with risk of cancer. The reasons for these associations, and for the

difference between males and females, are complex, as these results are a composite of many cancers and risk factors. They will be explored in more detail in the chapters relating to individual cancer sites.

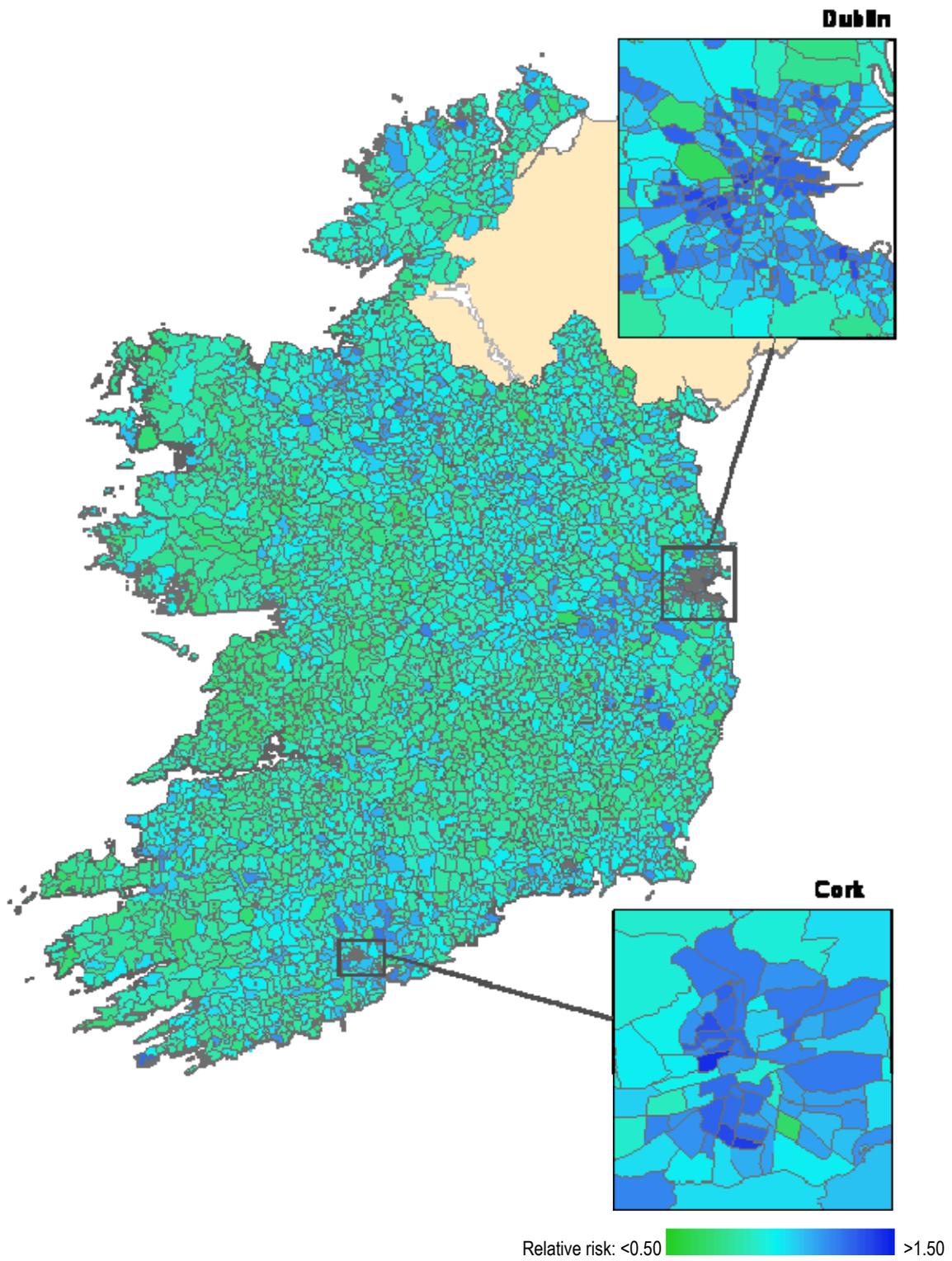
3.4 Mapping and geographical variation

Geographical variation

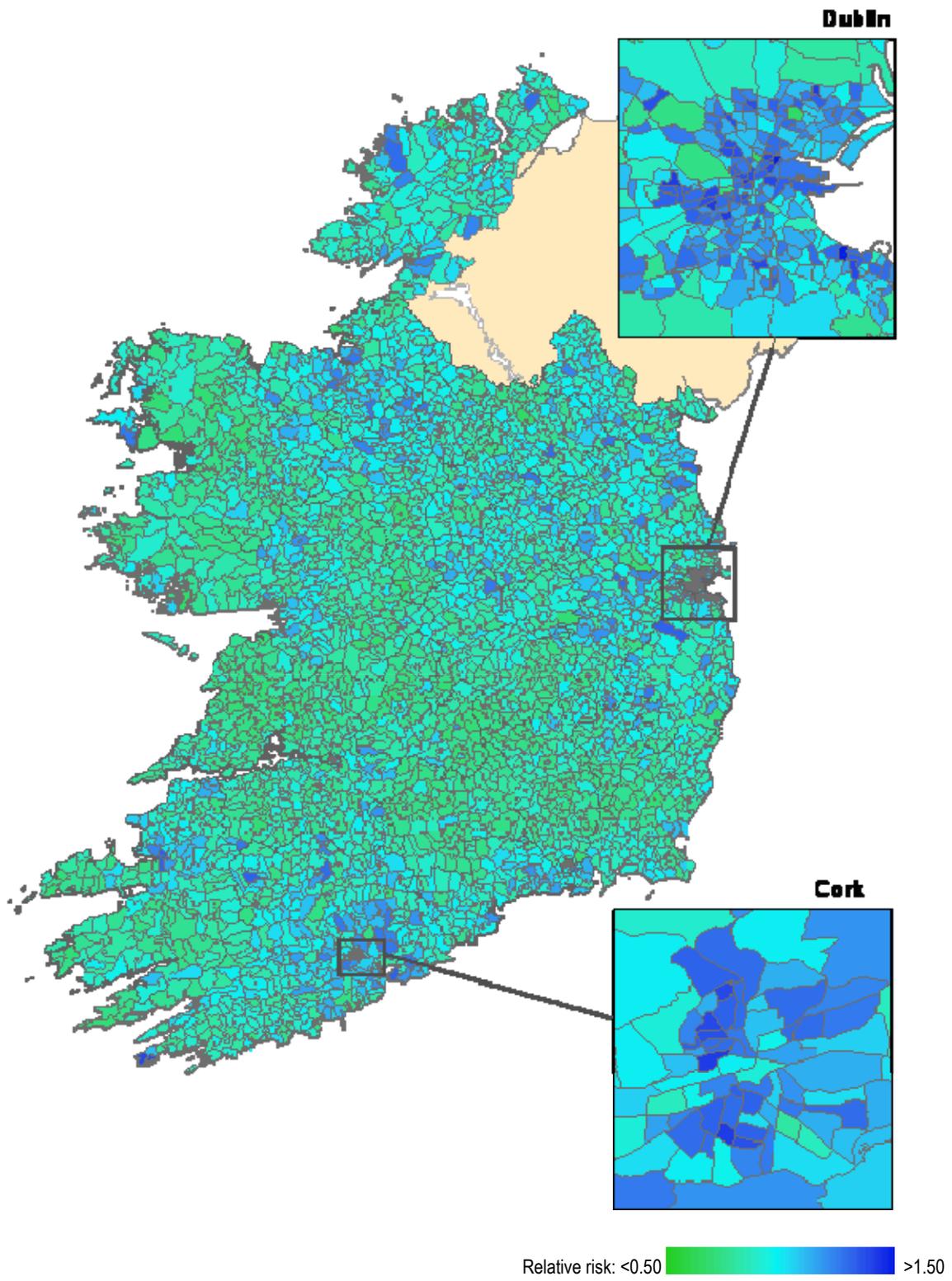
Cancer incidence in men showed more geographical variation than in women (maps 3.1-3.3). There were areas of higher incidence around Dublin and Cork and, for men, around some other urban centres. Incidence for both sexes also seemed to be higher in a band running across the northeast and north midlands, from Dublin to Sligo. There was no clear geographical pattern of incidence within either Dublin or Cork cities.

As with the associations between cancer incidence and population density, deprivation and other socio-economic variables, these geographical variations are a function of many cancers and many risk factors and are, therefore, almost impossible to interpret. Subsequent chapters provide information on geographical variation for individual cancer sites.

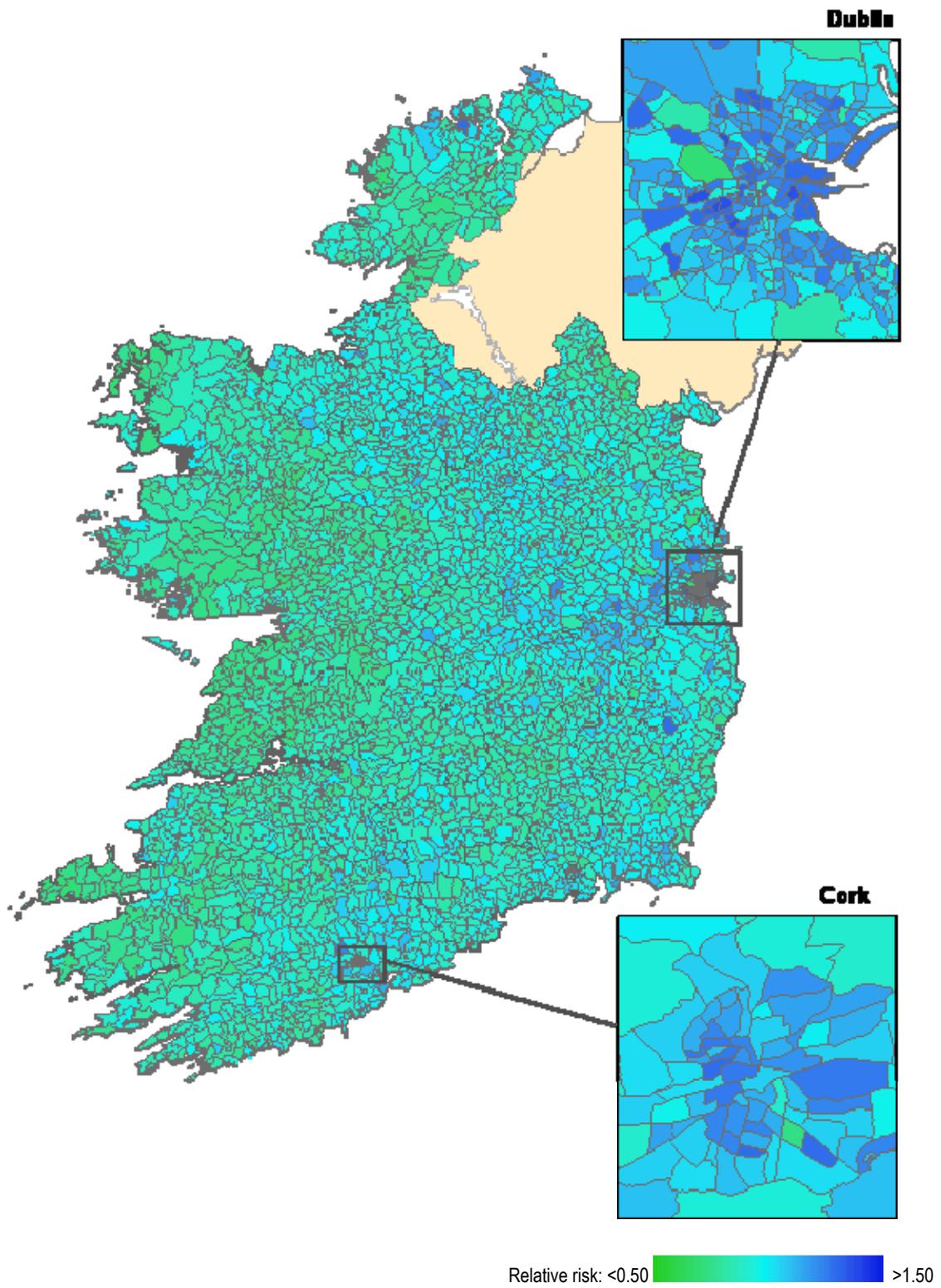
Map 3.1 All malignant cancers, smoothed relative risks: both sexes



Map 3.2 All malignant cancers, smoothed relative risks: males



Map 3.3 All malignant cancers, smoothed relative risks: females



4 Non-melanoma skin cancer

4.1 Summary

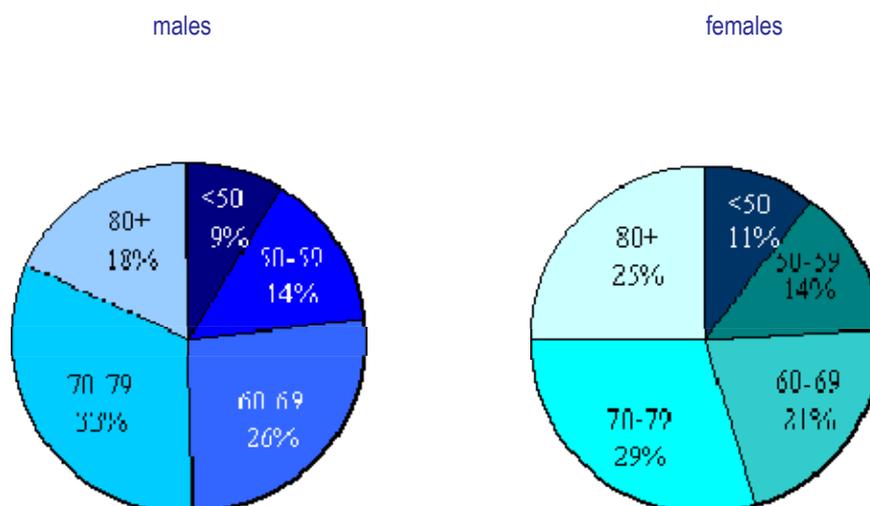
Non-melanoma skin cancer is the most commonly diagnosed cancer in Ireland, accounting for 27% of all malignant neoplasia (table 4.1). Each year, approximately 2,615 men and 2,330 women are diagnosed with a non-melanoma skin cancer. Incidence rates have remained stable during 1994-2003.

Table 4.1 Summary information for non-melanoma skin cancer in Ireland, 1994-2003

	females	males
% of all new cancer cases	27%	28%
Average number of new cases per year	2,330	2,615
Average number of deaths per year	12	23
Age standardised incidence rate per 100,000 (European standard population)	116.7	162.2
Estimated annual percentage change in rate 1994-2003	-0.2%	-1.3%

The incidence of non-melanoma skin cancer increases with increasing age (figure 4.1). The age distribution of cases is similar for men and women. Only around 10% of cases present in those aged under 50. Around one-fifth of cases occur in males 80 years old and over, and 26% in females. The largest number of cases in both sexes is in people aged 70 to 79.

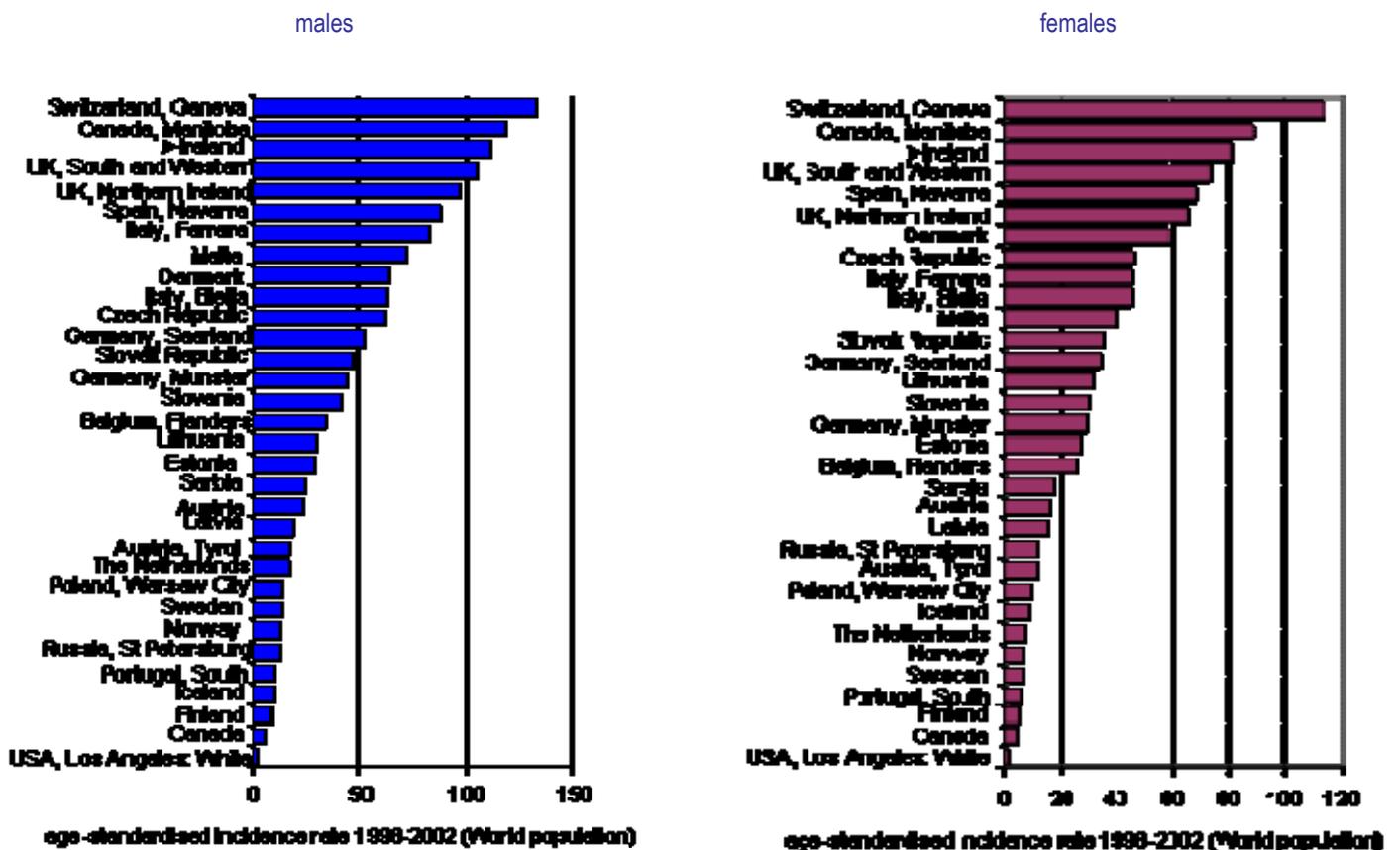
Figure 4.1 Age distribution of non-melanoma skin cancer cases, 1994-2003, males and females



4.2 International variations in incidence

Comprehensive (i.e. complete) registration of non-melanoma skin cancer is uncommon and no data are available for international comparison at country level. Figure 4.2 gives data on the incidence rate during 1998-2002 in individual cancer registries for a number of European and American countries. The registry with the highest incidence rate for each country is shown. The very broad range of incidence rates illustrates the wide differences in completeness of registration.

Figure 4.2 Incidence rate per 100,000 in 1998-2002 for selected cancer registries in Europe and USA: non-melanoma skin cancer



Source: Curado et al, 2007

4.3 Risk factors

Table 4.2 Risk factors for non-melanoma skin cancer, by strength of evidence

	Increases risk	Decreases risk
<i>Convincing or probable</i>	Sun exposure ^{1,2}	
	Skin colour ²	
	Ability to tan ²	
	Childhood freckling ²	
	Presence of benign sun damage in the skin ²	
	Sunbed/sunlamp use ³	
	Immune suppression ⁴	
	Arsenic in drinking water ⁵	
	Ionizing radiation exposure (including X-rays) ⁶	
	<i>Possible</i>	Infection with human papilloma viruses (HPV) ⁷

¹ International Agency for Research on Cancer, 1992; ² Armstrong and Kricger, 2001; ³ Karagas et al, 2002; ⁴ Saladi and Persaud, 2005; ⁵ World Cancer Research Fund / American Institute for Cancer Research, 2007; ⁶ Roewert-Huber et al, 2007; ⁷ International Agency for Research on Cancer, 2007a

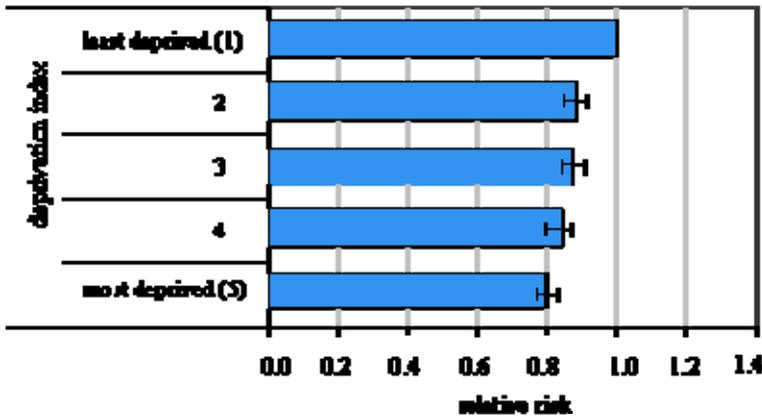
Risk factors for non-melanoma skin cancer are summarised in table 4.2. There are two main types of non-melanoma skin cancer - squamous cell carcinoma (SCC) and basal cell carcinoma (BCC). There is convincing evidence that both types are caused by exposure to ultraviolet (UV) radiation present in sunlight. Occupational sunlight exposure has been mainly associated with SCC and recreational exposure with BCC. Individuals with a lighter skin colour, less ability to tan, and who had freckles as a child, are at increased risk, as are those with solar keratoses (benign sun damage to the skin). Independently of sun exposure, use of artificial tanning devices which emit UV radiation, such as sunbeds or sunlamps, has been associated with raised risk of BCC and, especially, SCC.

Individuals who are immune suppressed, such as organ transplant recipients or those with AIDS, have a greatly increased risk of developing skin cancer. Residues of arsenic from agriculture, mining and industrial practices can end up in drinking water. Arsenic is carcinogenic (International Agency for Research on Cancer, 1987, International Agency for Research on Cancer, 2004a) and ingestion of these residues has been associated with increased skin cancer risk. Low-dose ionizing radiation exposure (e.g. for benign skin conditions such as acne) increases risk of BCC.

Human papilloma viruses (HPV) infect mucosal and cutaneous epithelia. There is limited evidence to suggest that infection with particular HPV types (genus-beta) is causally related to SCC (International Agency for Research on Cancer, 2007a).

4.4 Electoral district characteristics and cancer incidence

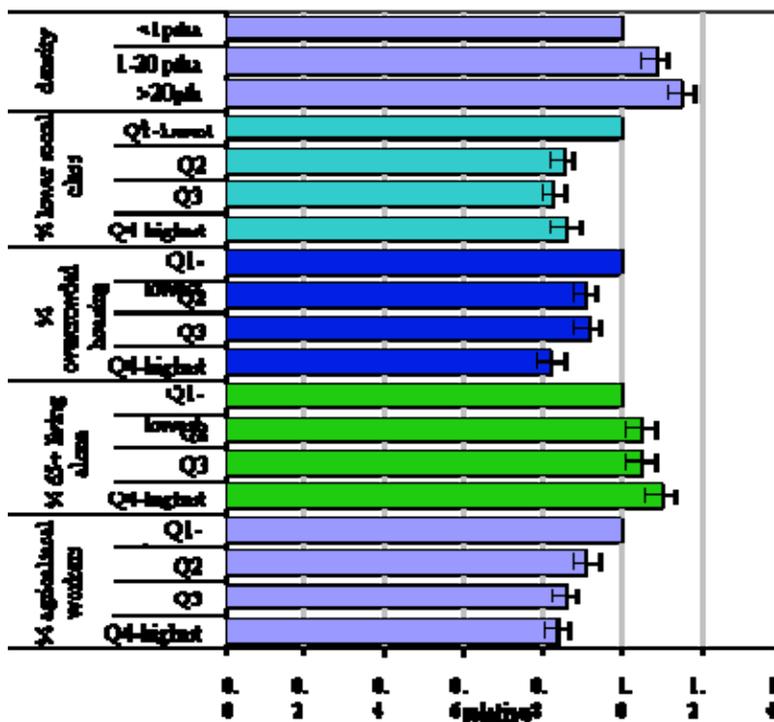
Figure 4.3 Adjusted relative risks of non-melanoma skin cancer by deprivation index: males



Non-melanoma skin cancer risk in men fell with increasing deprivation of the area of residence (figure 4.3). The most deprived areas had the lowest risk; it was 20% lower in these areas than in the least deprived areas (RR=0.80, 95% CI 0.77-0.83).

Adjusted for population density

Figure 4.4 Adjusted relative risks of non-melanoma skin cancer by area characteristics: males



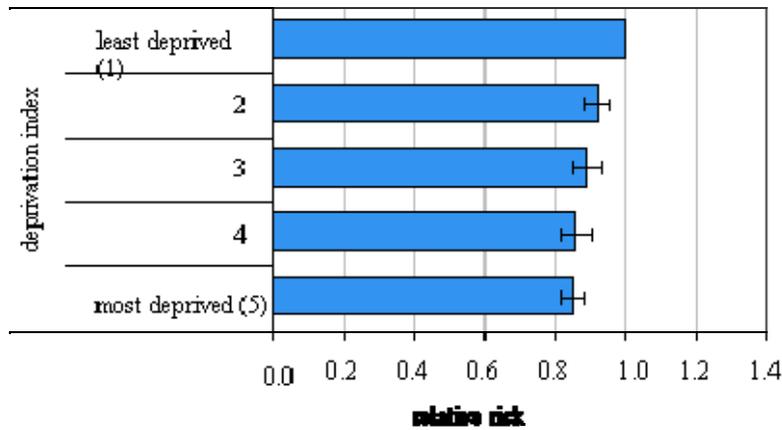
Compared to the most sparsely populated areas, areas with the highest population density had the highest risk of non-melanoma skin cancer in men (figure 4.4; RR=1.15, 95% CI 1.12-1.19). This pattern was also reflected in the inverse relationship between risk and proportion of agricultural workers.

A lower risk of non-melanoma skin cancer was also seen in areas with a higher proportion of overcrowded housing and those with a higher percentage of persons aged 65 and over who lived alone.

Areas with the lowest proportion of persons in lower social classes had the highest risk of non-melanoma skin cancer; there was no significant difference in risk between the other three quartiles.

All variables mutually adjusted except % of agricultural workers (not adjusted for density)

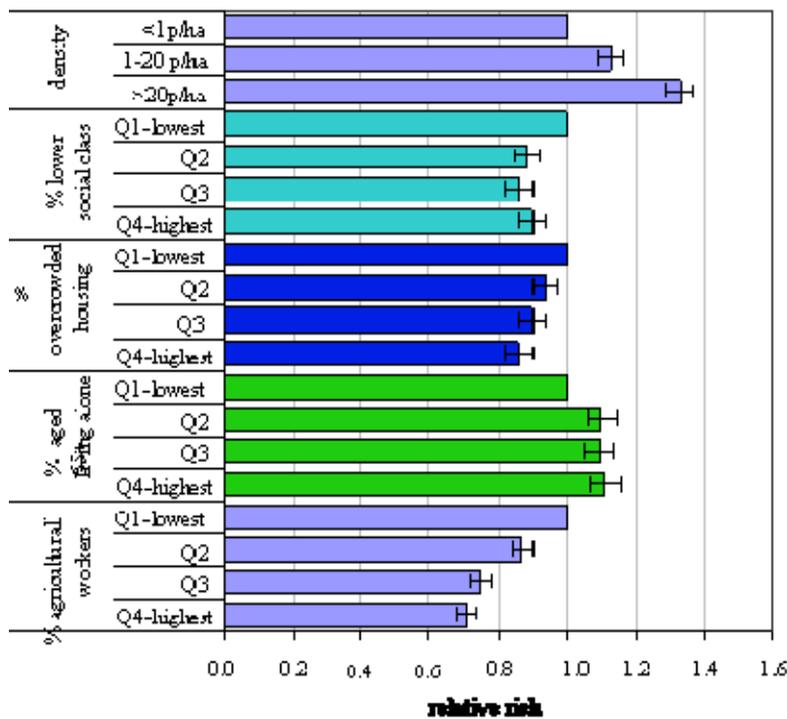
Figure 4.5 Adjusted relative risks of non-melanoma skin cancer by deprivation index: females



As with men, incidence of non-melanoma skin cancer incidence was associated with the index of deprivation (figure 4.5). Risk decreased with increasing deprivation. The most deprived areas had a 15% decrease in risk compared to the least deprived areas (RR=0.85, 95% CI 0.82-0.88).

Adjusted for population density

Figure 4.6 Adjusted relative risks of non-melanoma skin cancer by area characteristics: females



The most densely populated areas had a significantly higher risk of non-melanoma skin cancer in women than the most sparsely populated areas (figure 4.6; RR= 1.33 95% CI 1.29-1.37). In contrast, areas with higher proportions of early school leavers, overcrowded housing or lower proportions of agricultural workers were associated with significantly lower risk. As for males, areas with the lowest proportions in social class 5 or 6 had the highest incidence in women.

Areas in the 2nd-4th quartiles of the proportion of over 65 living alone had a slightly increased risk of non-melanoma skin cancer in women.

All variables mutually adjusted except % of agricultural workers (not adjusted for density)

Socio-economic variation

The pattern of incidence by socio-demographic variables was similar for men and women. Average population exposure to UV radiation would be expected to be highest in areas with a high proportion of outdoor workers - in Ireland these would be predominantly male workers in agriculture, fishing and construction. Female outdoor

workers are much less common, and would, historically, have been almost exclusively in agriculture. The similarity between male and female patterns argues against an occupational explanation for the observed variations, as does the higher incidence in urban and more affluent areas. The patterns may be due to higher awareness and detection rates in urban communities, or to a predominance of leisure-related UV exposure over occupational. More focussed studies would be needed to elucidate this issue.

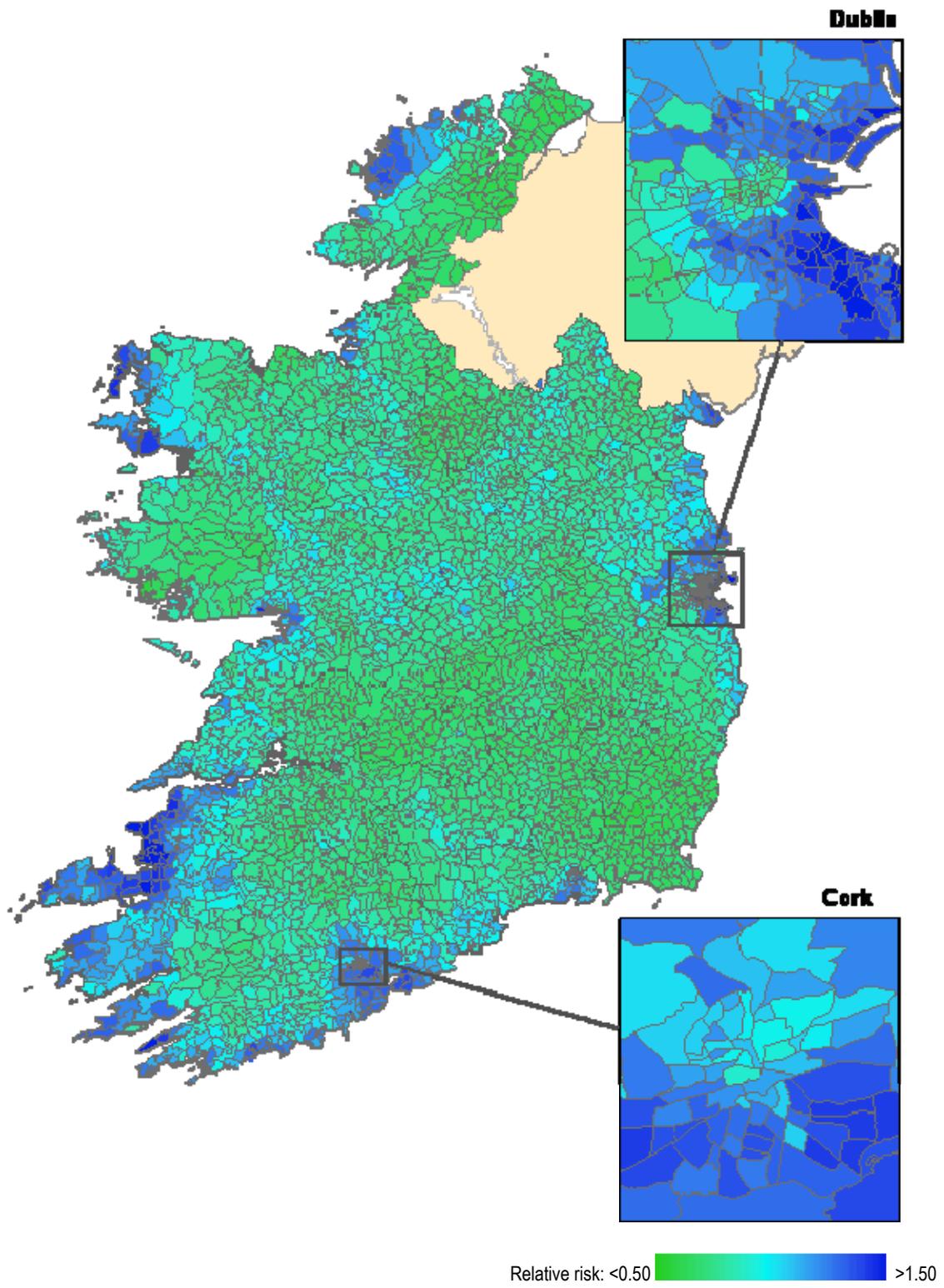
4.5 Mapping and geographical variation

Geographical variation

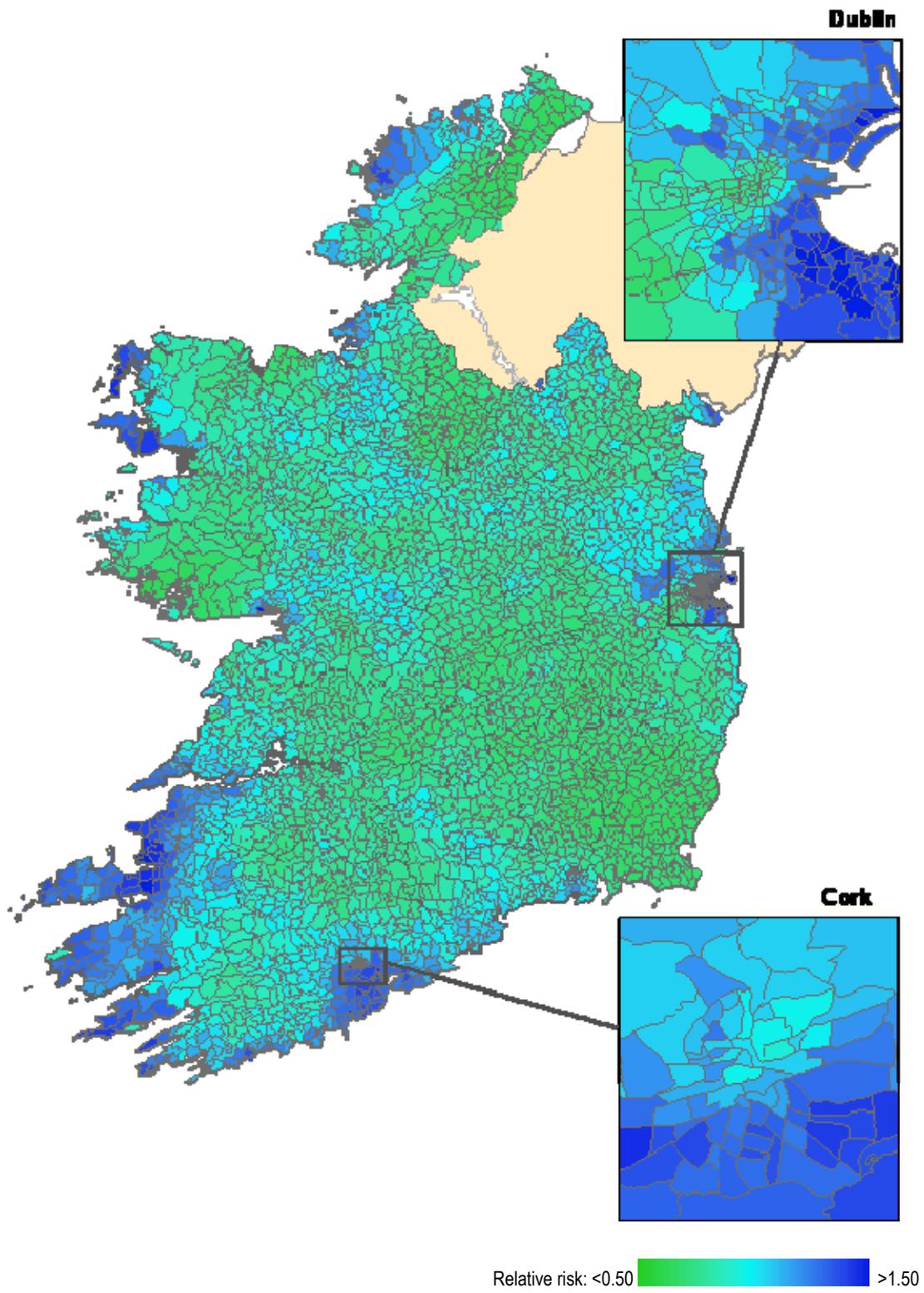
The geographical distribution of non-melanoma skin cancer was similar for men and women (maps 4.1-4.3), although the variation was somewhat more pronounced for men. Areas of high incidence were seen around the cities of Dublin, Cork, Galway and Waterford; in Cork and Dublin the areas of higher incidence were to the south and east of the cities, respectively. Outside the urban areas, regions of high incidence were observed in areas along the west coast in Donegal, Mayo, Clare, Kerry, west Cork (men) and also on the coast of Waterford (men).

Mean daily sunshine levels do not vary greatly across the country. They are highest in the southeast (an average of 4.3 hours daily at Rosslare during 1961-1990) and lowest in the west (3.0 hours daily in Claremorris). Therefore, overall population exposure to UV seems unlikely to explain the patterns seen. Although we are not aware of any studies on skin pigmentation in the Irish population, the homogeneity of the population makes it unlikely that pigmentation varies significantly from east to west. Recreational exposures and higher levels of surveillance are possible explanations for the high urban incidence. Outdoor occupations (farming, fishing and forestry) may partly explain the rural patterns in males; however, the counties with the highest percentage of males in these occupations (Roscommon, Leitrim, Tipperary and Waterford) did not have the highest observed incidence of non-melanoma skin cancer. Similarly, fewer than 3% of females listed farming, fishing or forestry as their occupation in the 2006 census, and the counties with the highest percentage of females in these outdoor occupations (Monaghan, Tipperary, Mayo and Waterford) did not have a markedly elevated incidence of non-melanoma skin cancers. However, non-melanoma skin cancer is a result of cumulative lifetime sun exposure, and occupational patterns may have been quite different in the past. Since exposures to the other putative risk factors for non-melanoma skin cancer (e.g. arsenic in drinking water) might be expected to be relatively uncommon, it seems unlikely that these could account for the geographical variations. Further study would be needed to better understand these patterns.

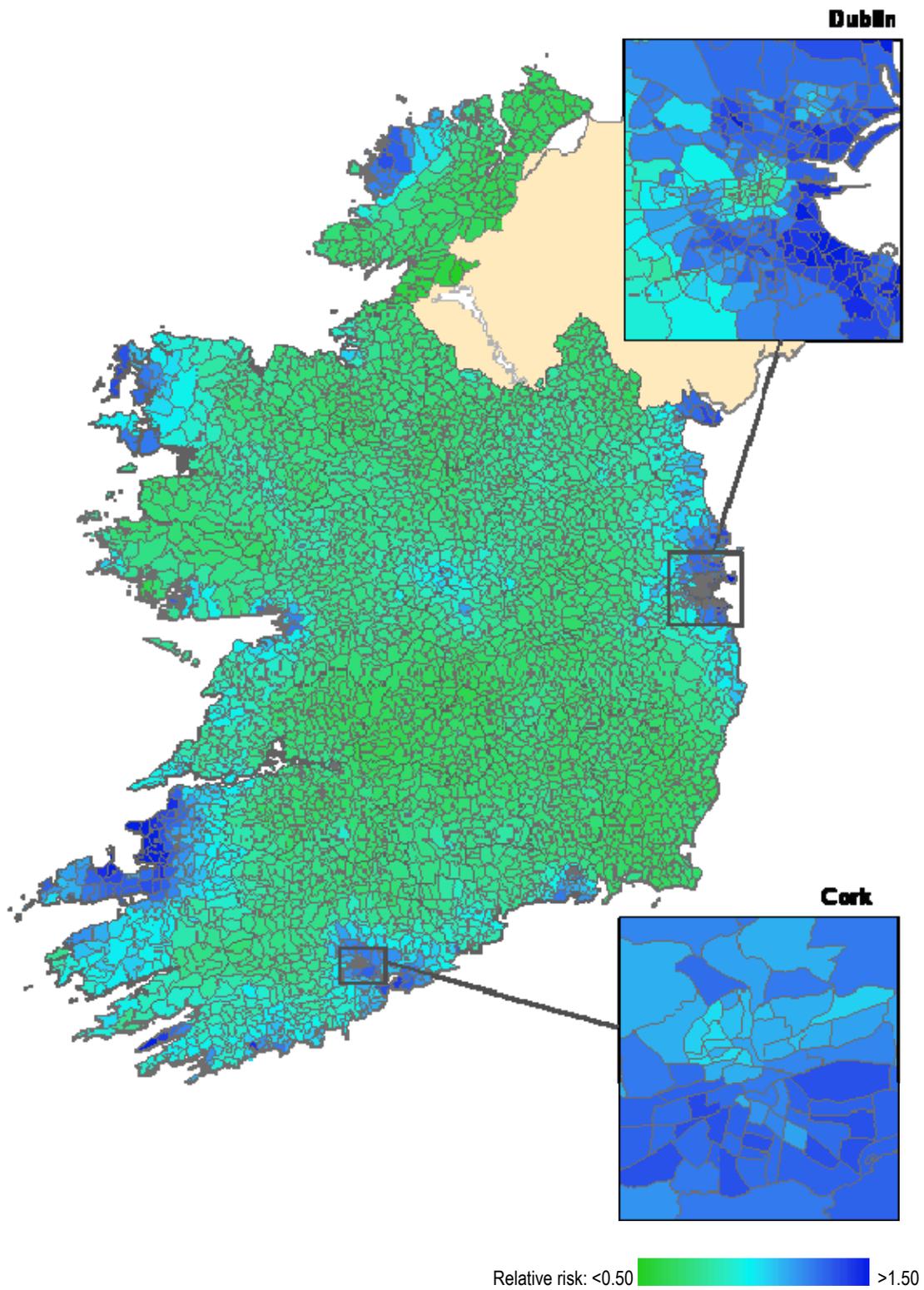
Map 4.1 Non-melanoma skin cancer, smoothed relative risks: both sexes



Map 4.2 Non-melanoma skin cancer, smoothed relative risks: males



Map 4.3 Non-melanoma skin cancer, smoothed relative risks: females



5 Breast cancer

5.1 Summary

Breast cancer accounts for 20% of all malignant neoplasms in women (table 5.1). If non-melanoma skin cancer is excluded, it is the most common cancer diagnosed in women in Ireland. Each year, approximately 1,820 women and 13 men are diagnosed with a malignant breast tumour. Incidence rates in women increased by 2.7% annually, between 1994 and 2003. Those in men changed little over time.

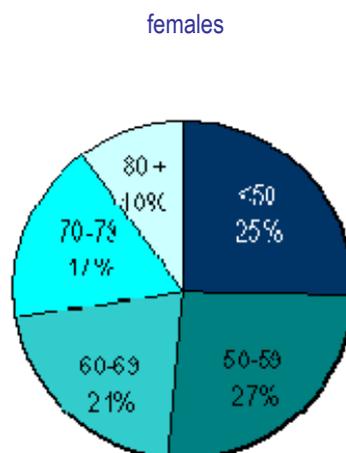
The remainder of this chapter relates only to breast cancer in women.

Table 5.1 Summary information for breast cancer in Ireland, 1994-2003

	females	males
% of all new cancer cases	20%	0.1%
% of all new cancer cases excluding non-melanoma skin cancer	28%	0.2%
Average number of new cases per year	1,820	13
Average number of deaths per year	640	5
Age standardised incidence rate per 100,000 (European standard population)	103.8	0.8
Estimated annual percentage change in rate 1994-2003	2.7%	-1.4%

The incidence of breast cancer, in common with most cancers, increases with increasing age (figure 5.1). Around 25% of cases present in those aged under 50, with a slightly larger percentage (27%) in those aged 50-59. 27% of cases occur in those aged over 70.

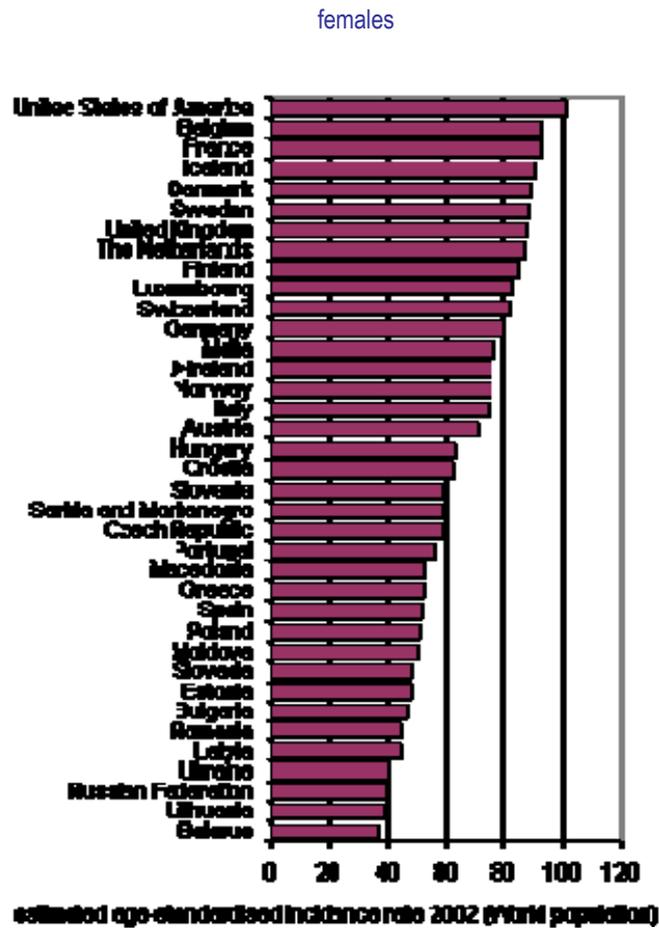
Figure 5.1 Age distribution of breast cancer cases, 1994-2003



5.2 International variations in incidence

Breast cancer incidence in women in Ireland is low compared to that in most other countries in western Europe although close to the average for Europe as a whole (figure 5.2). The rate in the USA exceeds rates in western Europe and Canada; this is likely to reflect differences in screening activity.

Figure 5.2 Estimated incidence rate per 100,000 in 2002 for Europe and USA: breast cancer



Source: GLOBOCAN 2002 (Ferlay et al, 2004)

5.3 Risk factors

Table 5.2 Risk factors for breast cancer, by strength of evidence

	Increases risk	Decreases risk
<i>Convincing or probable</i>	Family history of breast cancer ^{1,2}	Breastfeeding ^{6,11}
	Nulliparity and low parity ^{2,3}	Physical activity ^{5,6}
	Late age at first pregnancy ^{2,3}	Greater body fat (pre-menopausal breast cancer) ^{5,6}
	Late natural menopause ^{2,3}	Tamoxifen and raloxifene ^{12,13,14}
	Early menarche ^{2,3}	
	Oral contraceptives ^{4,5}	
	Hormone replacement therapy ^{4,5}	
	Body fatness, abdominal fatness and weight gain in adulthood (post-menopausal breast cancer) ^{6,7}	
	Alcohol ^{7,8}	
	Ionizing radiation exposure (including X-rays and gamma radiation) ⁹	
<i>Possible</i>	High socio-economic status ¹⁰	Aspirin and other non-steroidal anti-inflammatory drugs ¹⁵

¹ First degree relatives(s) with breast cancer; ² Veronesi et al, 2005; ³ Key et al, 2001; ⁴ International Agency for Research on Cancer, 2007b; ⁵ combined oestrogen-progestogen formulations; ⁶ International Agency for Research on Cancer, 2002; ⁷ World Cancer Research Fund / American Institute for Cancer Research, 2007; ⁸ International Agency for Research on Cancer, in press; ⁹ US Department of Health and Human Services, 2005; ¹⁰ Faggiano et al, 1997; ¹¹ Collaborative Group on Hormonal Factors in Breast Care, 2002; ¹² in pre-menopausal women at high breast cancer risk; ¹³ Levine et al, 2001; ¹⁴ Wickerham et al, 2009; ¹⁵ Bosetti et al, 2006

A woman's chance of developing breast cancer is increased if any of her first degree female relatives had the disease; risk rises further if more than one relative has been affected, especially if this was at a young age (Veronesi et al, 2005). This points to the importance of genetic factors in breast cancer. Up to 10% of cases are hereditary and women who have mutations in the *BRCA1* or *BRCA2* genes have a very high chance of developing breast cancer over their lifetime (Antoniou and Easton, 2006). Recent genome-wide association studies have identified several new candidate loci, some of which appear to be associated with particular subtypes of breast cancer, but considerable further work will be needed to establish the specific causal variants involved (Easton and Eeles, 2008).

Lifetime exposure to oestrogen is the major determinant of breast cancer risk (table 5.2). Early menarche (onset of menstrual periods), late natural menopause, not bearing children (or having few children), and late age at first pregnancy (>30) are all markers of increased endogenous oestrogen exposure and are associated with raised risk of the disease. Exposure to exogenous sources of oestrogen (i.e. using oral contraceptives or hormone replacement therapy (HRT)) also increases risk. On the other hand, in pre-menopausal women at high risk of

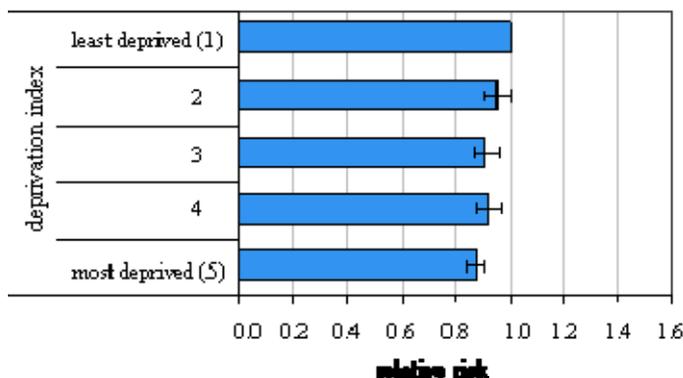
breast cancer, the anti-oestrogenic drugs tamoxifene and raloxifene reduce the chances of developing the disease by about half.

In terms of lifestyle factors, there is convincing evidence that body fatness and physical activity levels affect risk. Risk of post-menopausal breast cancer is increased in women with higher levels of body fatness, particularly those with fat stored around the abdomen, and in those who gain weight during adult life. In contrast, greater body fatness is associated with decreased risk of pre-menopausal breast cancer. Higher levels of physical activity are related to decreased risk of both pre- and post-menopausal disease. Alcohol is a clearly established cause of both pre-menopausal and post-menopausal breast cancer.

Women with a higher socio-economic status have consistently been found to be at increased risk of breast cancer. It is likely that this represents socio-economic variation in risk factors for the disease.

5.4 Electoral district characteristics and cancer incidence

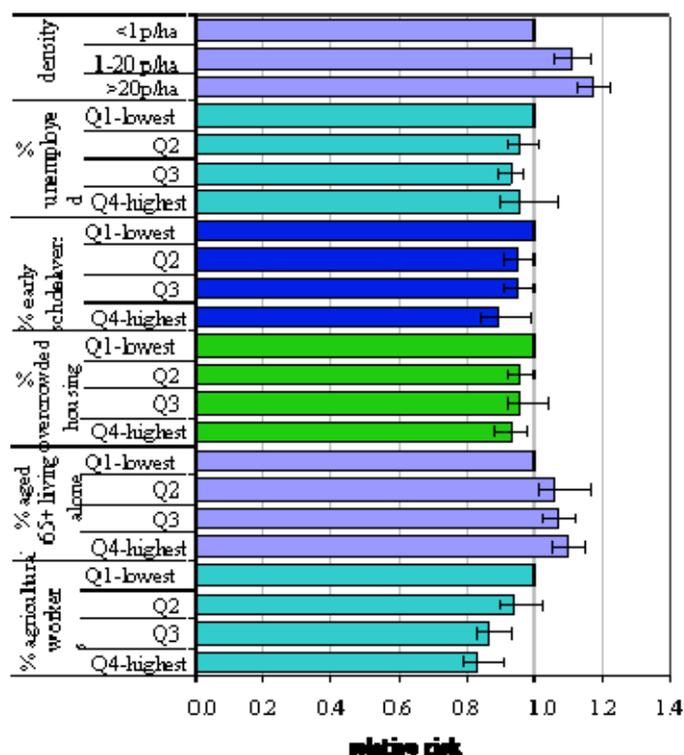
Figure 5.3 Adjusted relative risks of breast cancer by deprivation index: females



The incidence of female breast cancer decreased with increasing deprivation (figure 5.3). The most deprived areas were associated with a 12% lower risk than the least deprived areas (RR=0.88, 95% CI 0.84-0.91).

Adjusted for population density

Figure 5.4 Adjusted relative risks of breast cancer by area characteristics: females



Breast cancer risk was positively associated with population density: women resident in urban areas (density >20p/ha) had a 17% higher risk than women living in the lowest density areas (figure 5.4).

Areas with the highest proportion of early school leavers, and those with the highest proportion of agricultural workers, were associated with a reduced risk of breast cancer. Areas with higher levels of unemployment also had a slightly lower risk, but the association was weak.

The risk of breast cancer was significantly increased in areas with a high proportion of people aged 65 and older living alone.

All variables mutually adjusted except % of agricultural workers (not adjusted for density)

Socio-economic variation

The observed inverse association between breast cancer and deprivation is consistent with many other studies. The higher incidence in urban areas (which was seen after adjustment for socio-economic factors) is more surprising. However, population-based breast screening was available in the largest urban area, Dublin, from 2000 onwards and is likely to have affected the incidence figures. Women from urban areas also have easier access to

mammography, for both screening (outwith the programme) and symptomatic diagnosis. The association between breast cancer and higher proportions of people over 65 living alone is intriguing and more difficult to explain.

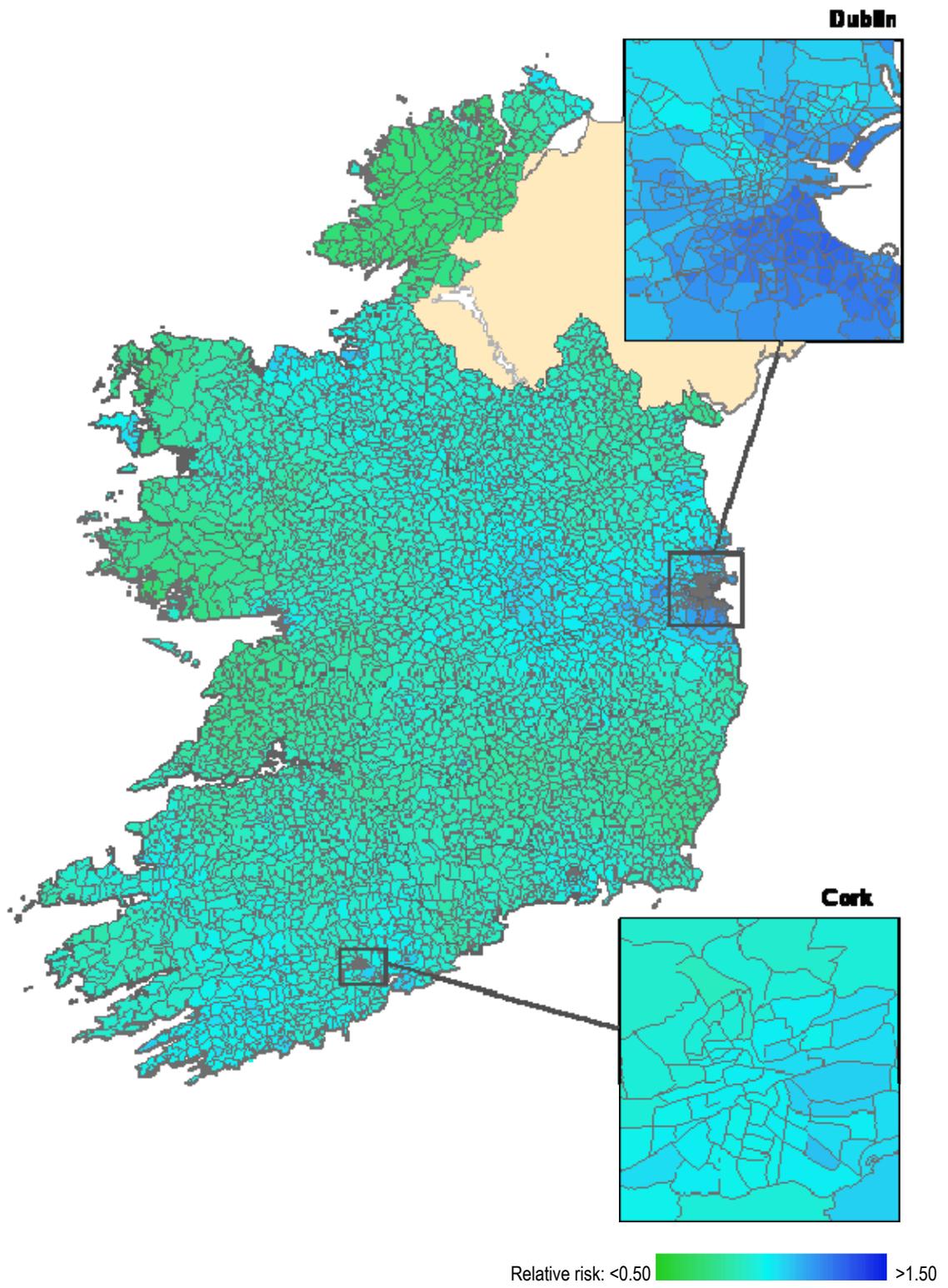
5.5 Mapping and geographical variation

Geographical variation

The geographical variation in breast cancer incidence was relatively modest. The areas of highest incidence were around the major urban areas - Dublin (especially), Cork, Galway, Waterford, and Sligo, but not Limerick (map 5.1). Outside these areas, there was a slightly increased incidence in west Cork, north Kerry, and a large area in the east Midlands. Within the two major urban areas, the incidence in southeast Dublin was clearly higher than that in the north and west, while in Cork the geographical pattern was less pronounced, but there was a suggestion of higher incidence in the southern suburbs.

Breast cancer incidence is strongly confounded by the presence and coverage of screening activity, which will tend to increase incidence, particularly during the initial phase. Organised screening began in Ireland in the eastern part of the country in 2000, and this may account for the higher incidence around Dublin and in the east Midlands. Screening outside the organised national programme may be responsible for much of the other excess of cases around the urban areas. Other than the relationship with urban areas and screening, the geographical pattern of breast cancer incidence showed no clear similarities with the distribution of known risk factors such as obesity, alcohol or social class (as measured by income; Appendix 1). There were some similarities with the distribution of levels of private health insurance (Appendix 1).

Map 5.1 Breast cancer, smoothed relative risks: females



6 Colorectal cancer

6.1 Summary

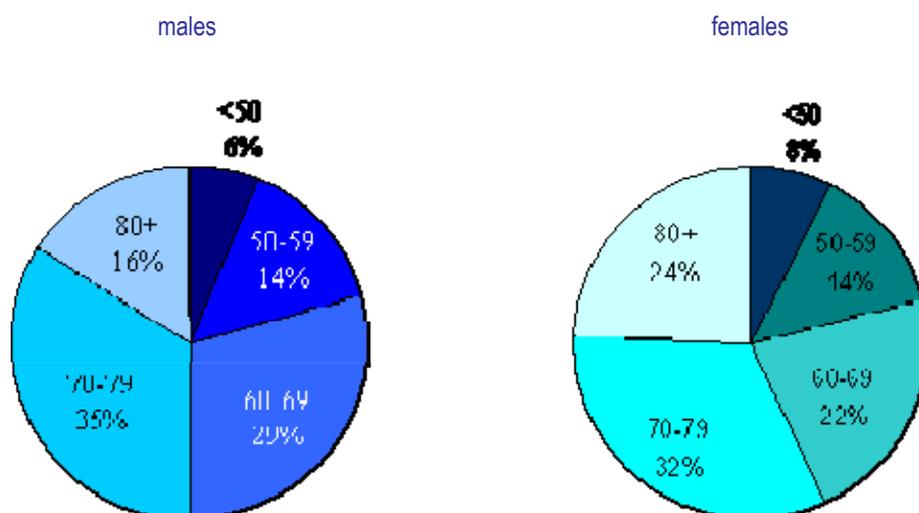
Colorectal cancer is the second most common cancer in Ireland (excluding non-melanoma skin cancer). It accounts for 12% of all malignant neoplasia in females and 15% in males (table 6.1). Each year, approximately 1,032 men and 787 women are diagnosed with a colorectal tumour. 69% of these cancers arise in the colon and 23% in the rectum. During 1994-2003, incidence rates decreased slightly in both sexes.

Table 6.1 Summary information for colorectal cancer in Ireland, 1994-2003

	females	males
% of all new cancer cases	9%	11%
% of all new cancer cases excluding non-melanoma skin cancer	12%	15%
Average number of new cases per year	787	1,032
Average number of deaths per year	405	521
Age standardised incidence rate per 100,000 (European standard population)	39.3	64.0
Estimated annual percentage change in rate 1994-2003	-0.4%	-0.2%

The majority of colorectal cancers are diagnosed in individuals aged 70 and older - 51% of cancers in males and 55% in females (figure 6.1). The age distribution is similar in both sexes, although with a higher proportion of cases in men aged 60-69 (29%, compared to 22% in women) and a higher proportion in women aged 80 and older (24% compared to 16% in women).

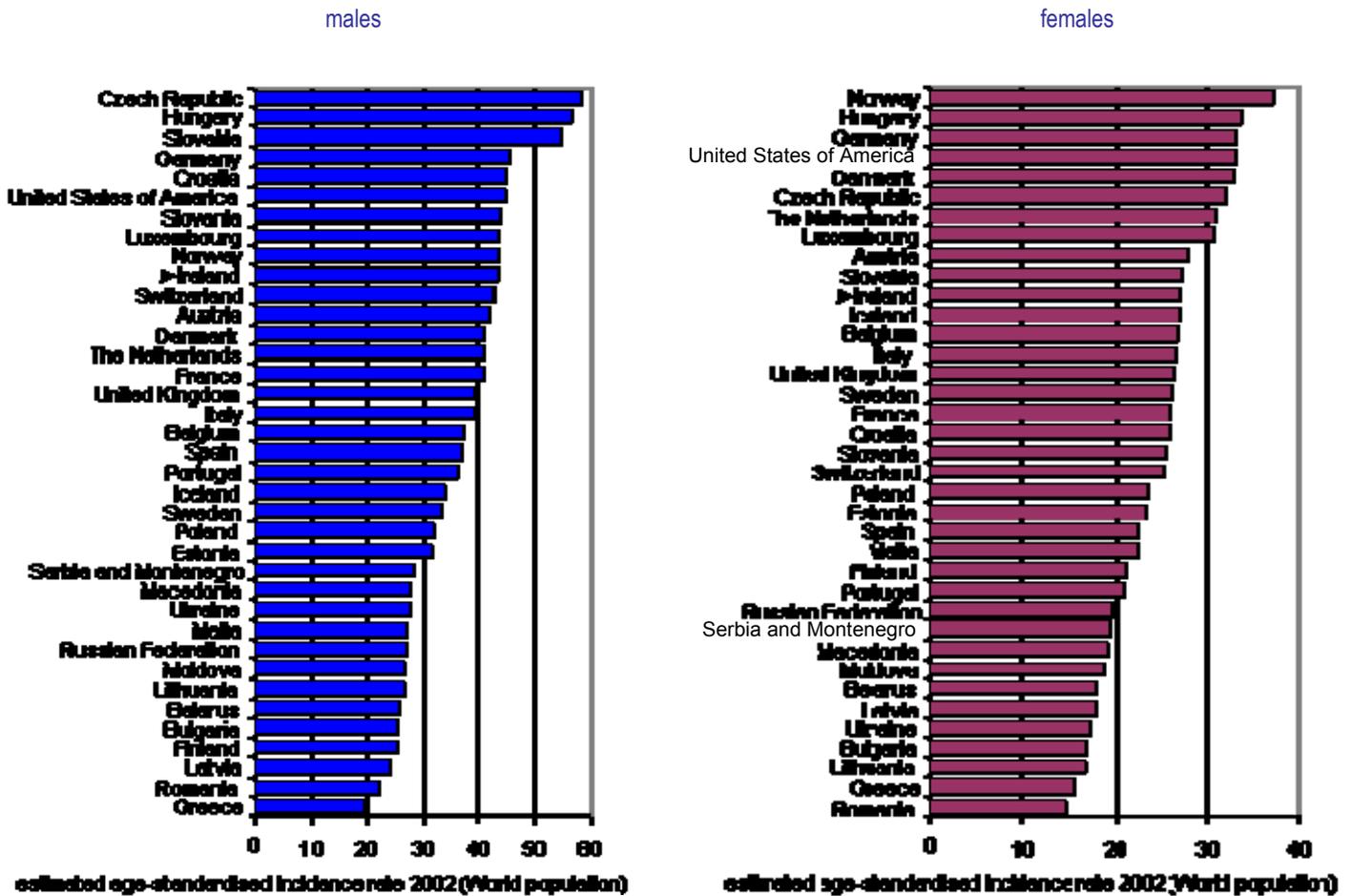
Figure 6.1 Age distribution of colorectal cancer cases, 1994-2003, males and females



6.2 International variations in incidence

Colorectal cancer incidence in both men and women in Ireland is in the upper half of rates across western Europe (figure 6.2). The rate among men in Ireland exceeds that for men in the UK by 10%, while the rate for women is almost the same in the two countries.

Figure 6.2 Estimated incidence rate per 100,000 in 2002 for Europe and USA: colorectal cancer



Source: GLOBOCAN 2002 (Ferlay et al, 2004)

6.3 Risk factors

Table 6.2 Risk factors for colorectal cancer, by strength of evidence

	Increases risk	Decreases risk
<i>Convincing or probable</i>	Family history of colorectal cancer ^{1,2}	Physical activity ^{3,4}
	Body fatness, in particular, abdominal fatness ^{3,4}	Foods containing dietary fibre ⁴
	Alcohol ^{4,5}	Garlic ⁴
	Red and processed meat ⁴	Milk and/or calcium ⁴
		Hormone replacement therapy ⁸
		Aspirin and other non-steroidal anti-inflammatory drugs ⁹
<i>Possible</i>	Tobacco smoking ^{6,7}	Non starchy vegetables ^{4,10}
		Fruit ^{4,10}
		Fish ⁴
		Oral contraceptives ⁸

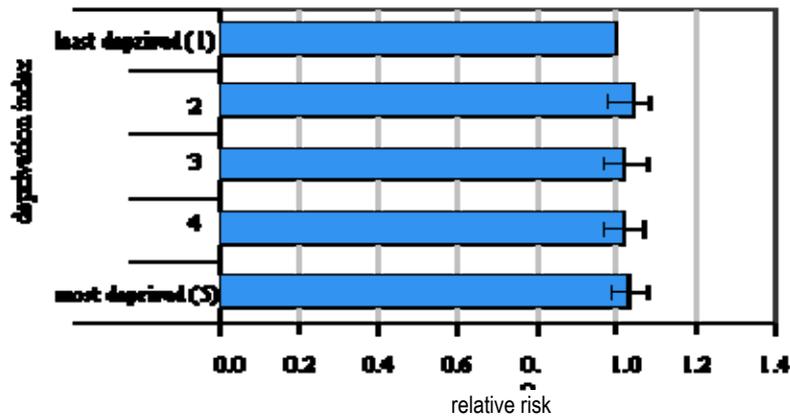
¹ First degree relative with colorectal cancer; ² Johns and Houlston, 2001; ³ International Agency for Research on Cancer, 2002; ⁴ World Cancer Research Fund / American Institute for Cancer Research, 2007; ⁵ International Agency for Research on Cancer, in press; ⁶ Giovannucci, 2001; ⁷ International Agency for Research on Cancer, 2004b; ⁸ International Agency for Research on Cancer, 2007b; ⁹ International Agency for Research on Cancer, 1997; ¹⁰ International Agency for Research on Cancer, 2003

Up to 10% of colorectal cancers are hereditary and most are due to the genetic syndromes of familial adenomatous polyposis (FAP) and hereditary non-polyposis colorectal cancer (HNPCC) (Hawkins and Ward, 2001). Excluding these syndromes, individuals who have a first degree relative with colorectal cancer have around a two-fold increased risk of developing the disease themselves. Similarly to the other common cancers, recent genome-wide association studies have revealed several more candidate loci for predisposition to colorectal cancer, but the specific genes involved have not yet been identified (Easton and Eeles, 2008).

Lifestyle factors are extremely important in colorectal cancer (table 6.2). There is strong evidence that higher levels of body fatness, and in particular central adiposity, are positively associated with risk. On the other hand, there is a consistent inverse association with physical activity, particularly for colon cancer, and risk decreases in a dose-response fashion with increased frequency or intensity of activity. In terms of diet, alcohol is a cause of both colon and rectal cancers and a large number of studies have found increased risk in those with higher intakes of red and processed meats (meats preserved by smoking, curing or salting, such as ham, bacon or salami). Several other aspects of diet have been associated with lower risk, including higher intakes of foods containing dietary fibre, milk and/or calcium and garlic. Increased consumption of fish, fruit and non-starchy vegetables may also reduce risk. There are suggestions that smoking is associated with increased colorectal cancer risk with a lag period of 35 years or more, but it is possible that this may be due to residual confounding (International Agency for Research on Cancer, 2004b). There is convincing evidence that regular use of aspirin or other non-steroidal anti-inflammatory drugs may reduce colorectal cancer risk by up to half. Risk is decreased in women taking hormone replacement therapy and may also be reduced in those who have taken oral contraceptives.

6.4 Electoral district characteristics and cancer incidence

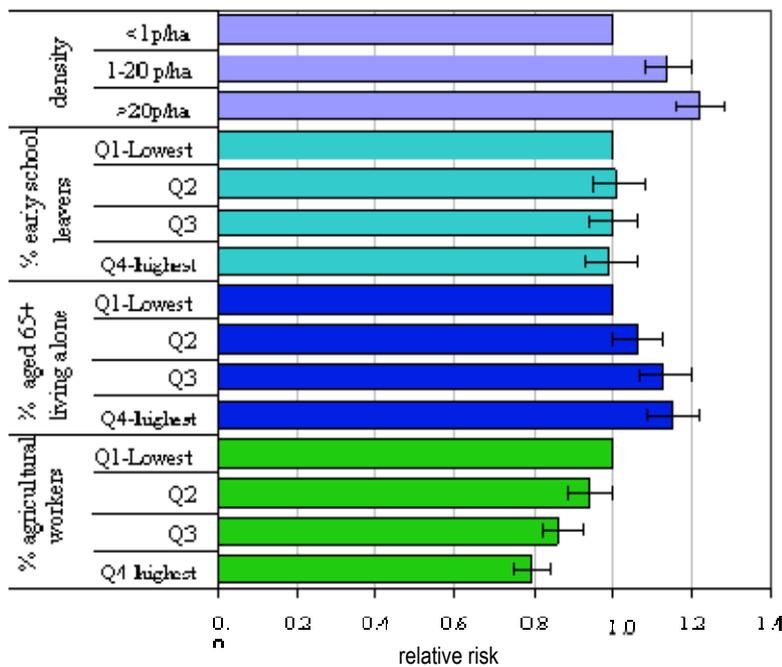
Figure 6.3 Adjusted relative risks of colorectal cancer by deprivation index: males



Adjusted for population density

A modest association was found between deprivation and colorectal cancer incidence in men (figure 6.3). Those living in the most deprived areas had a small increased risk of being diagnosed, compared to those resident in the least deprived areas (RR=1.06, 95% CI 1.00-1.12).

Figure 6.4 Adjusted relative risks of colorectal cancer by area characteristics: males



All variables mutually adjusted except % of agricultural workers (not adjusted for density)

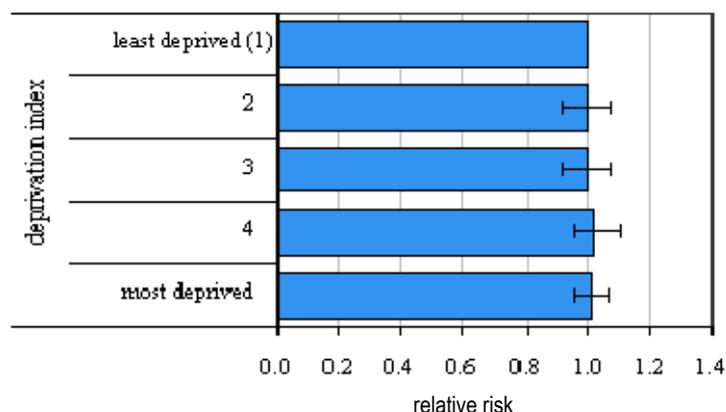
There was a clear positive association between population density and colorectal cancer incidence in men (figure 6.4), with risk more than 20% higher in the most densely, compared to the least densely, populated areas (RR=1.22, 95% CI 1.16-1.28).

Consistent with this, areas with higher numbers of agricultural workers had lower risk.

There was no association with any other measures of socio-economic status.

As with most other cancers, areas with a high proportion of persons aged over 65 who lived alone had a higher risk of colorectal cancer.

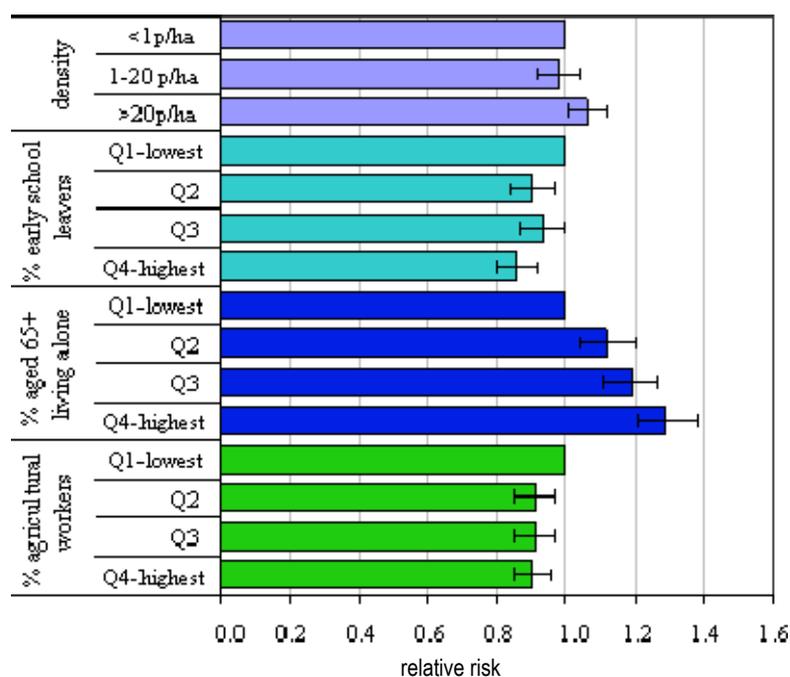
Figure 6.5 Adjusted relative risks of colorectal cancer by deprivation index: females



No association was found between deprivation and colorectal cancer incidence in women (figure 6.5).

Adjusted for population density

Figure 6.6 Adjusted relative risks of colorectal cancer by area characteristics: females



The association of high population density with increased colorectal cancer risk was weaker for women than for men, as was the link to the proportion of agricultural workers in the area (figure 6.6).

Areas with the highest proportion of early school leavers had a significantly lower risk.

There was a strong positive relationship between the proportion of persons aged over 65 living alone and colorectal cancer in females.

All variables mutually adjusted except % of agricultural workers (not adjusted for density)

Socio-economic variation

Deprivation was only weakly associated with colorectal cancer incidence in males, and not in females. Generally, the evidence on socio-economic status and colorectal cancer is inconsistent (Faggiano et al, 1997), but it is intriguing that a similar finding was reported in the UK (National Cancer Intelligence Network, 2008). For both sexes, areas of high population density were associated with increased risk, but this association was much stronger for men. For women, on the other hand, there was a significant relationship between incidence and the

proportion of early school leavers, which was not seen for men. These relationships suggest somewhat different patterns of risk factors for men and women, which would be in keeping with aspects of the aetiological evidence, such as that relating to the role of exogenous hormones. Different dietary patterns and the relationship of these with socio-economic status may also account for the male/female differences observed.

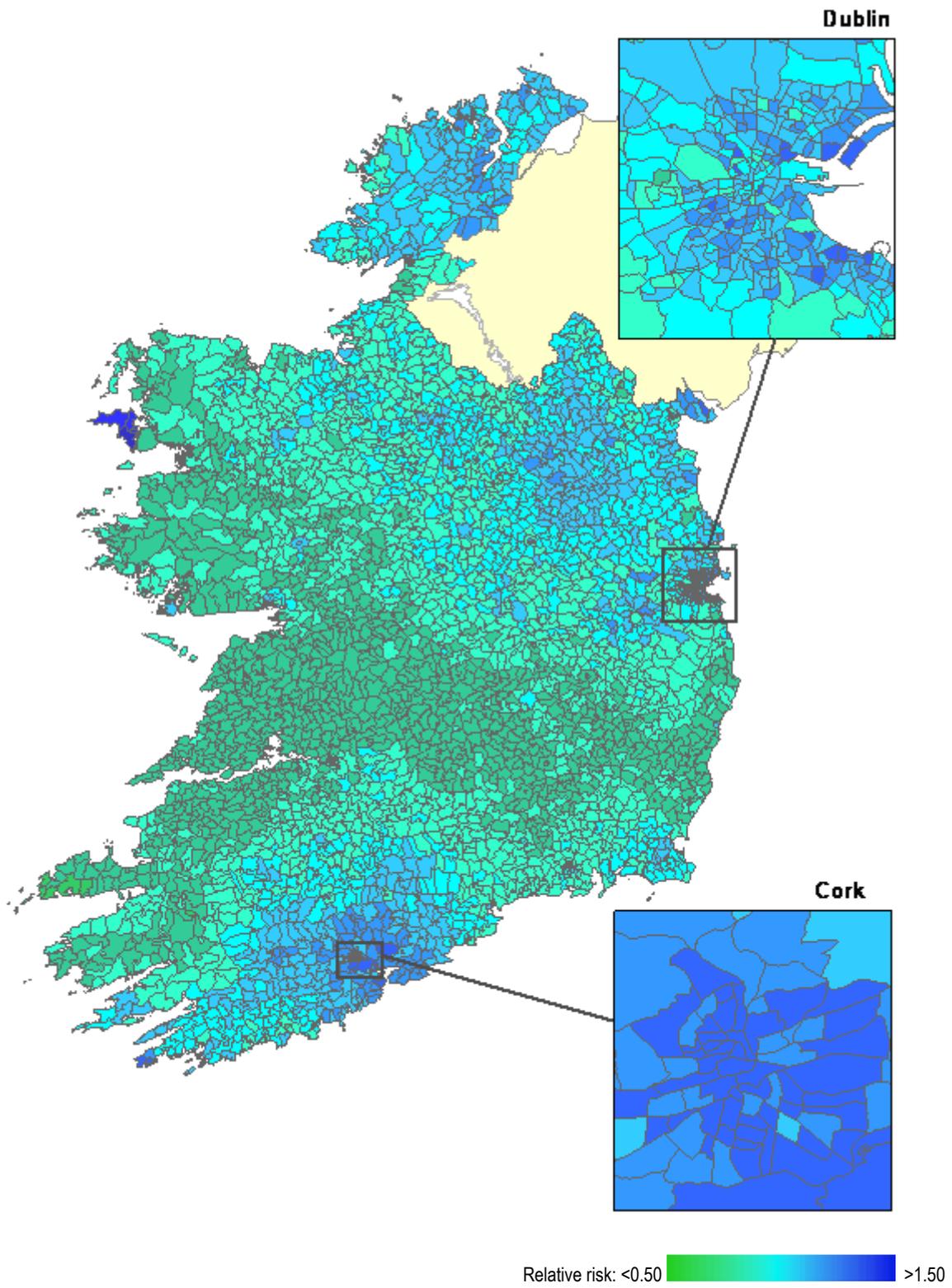
6.5 Mapping and geographical variation

Geographical variation

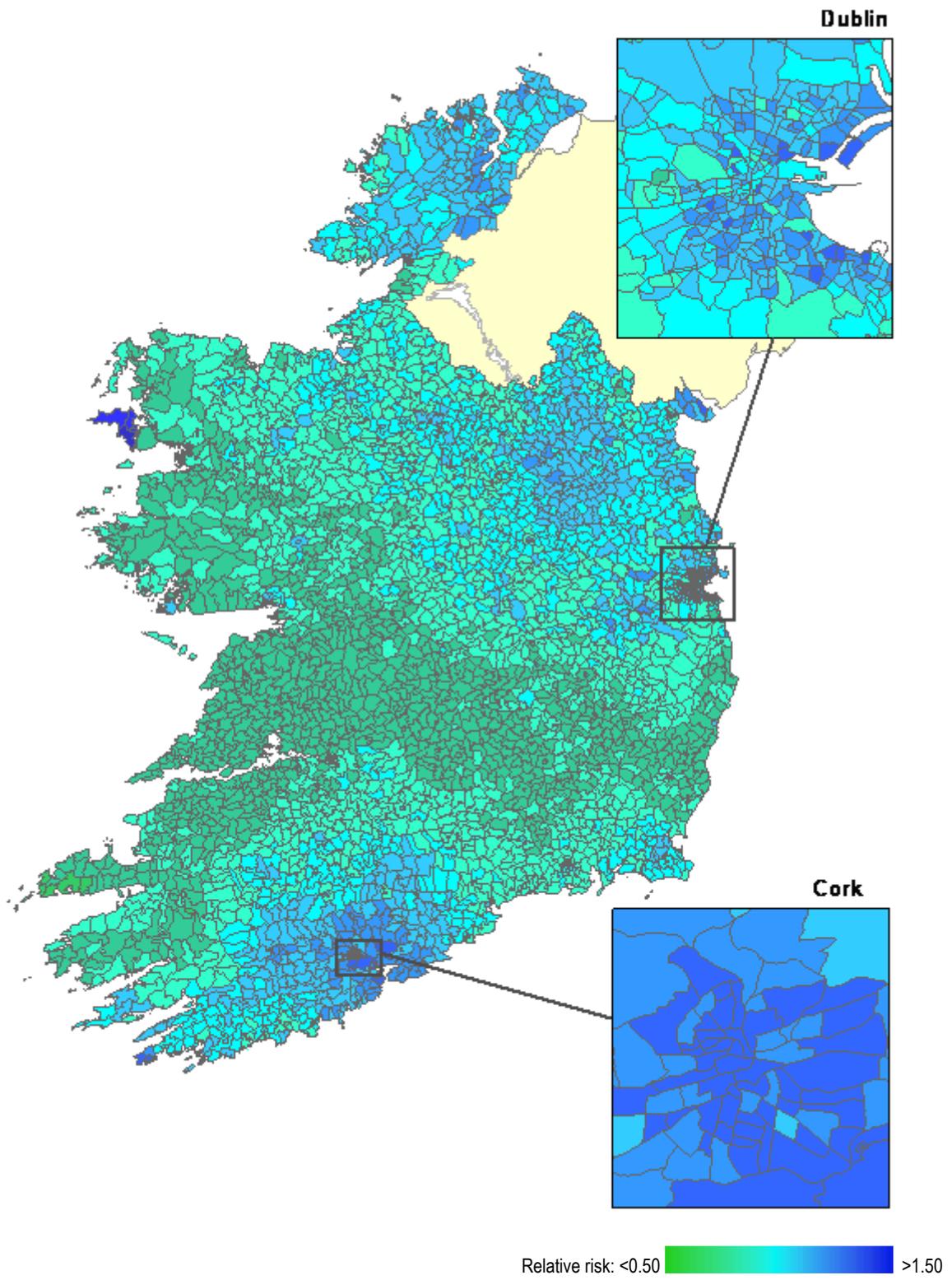
Compared to some other cancer sites, the geographical variation in colorectal cancer incidence was relatively modest. For both sexes combined, colorectal cancer incidence was higher than average in two areas - in Co. Cork, in an area centred on Cork City but extending into the far southwest, and in the north and centre of the country, in a broad band from Dublin heading through the northeast towards Donegal (map 6.1). Incidence also seemed to be higher in south Wexford. In the urban areas of Dublin and Cork, there was no overall geographical pattern, but the overall incidence was higher in Cork than Dublin. The patterns were similar when males and females were considered separately, although for males the area of high incidence in the north was largely confined to the northeast, while for women there was more marked high incidence in the centre of the country and in the northwest in particular (maps 6.2 and 6.3).

Comparing these patterns with the SLÁN risk factor maps (Appendix 1), the closest match seems to be with areas with a high prevalence of obesity. The geographical distribution of low fibre intake is quite different from that of colorectal cancer, despite its known association with higher cancer risk. There was no striking correspondence between the distribution of heavy alcohol consumption and that of colorectal cancer.

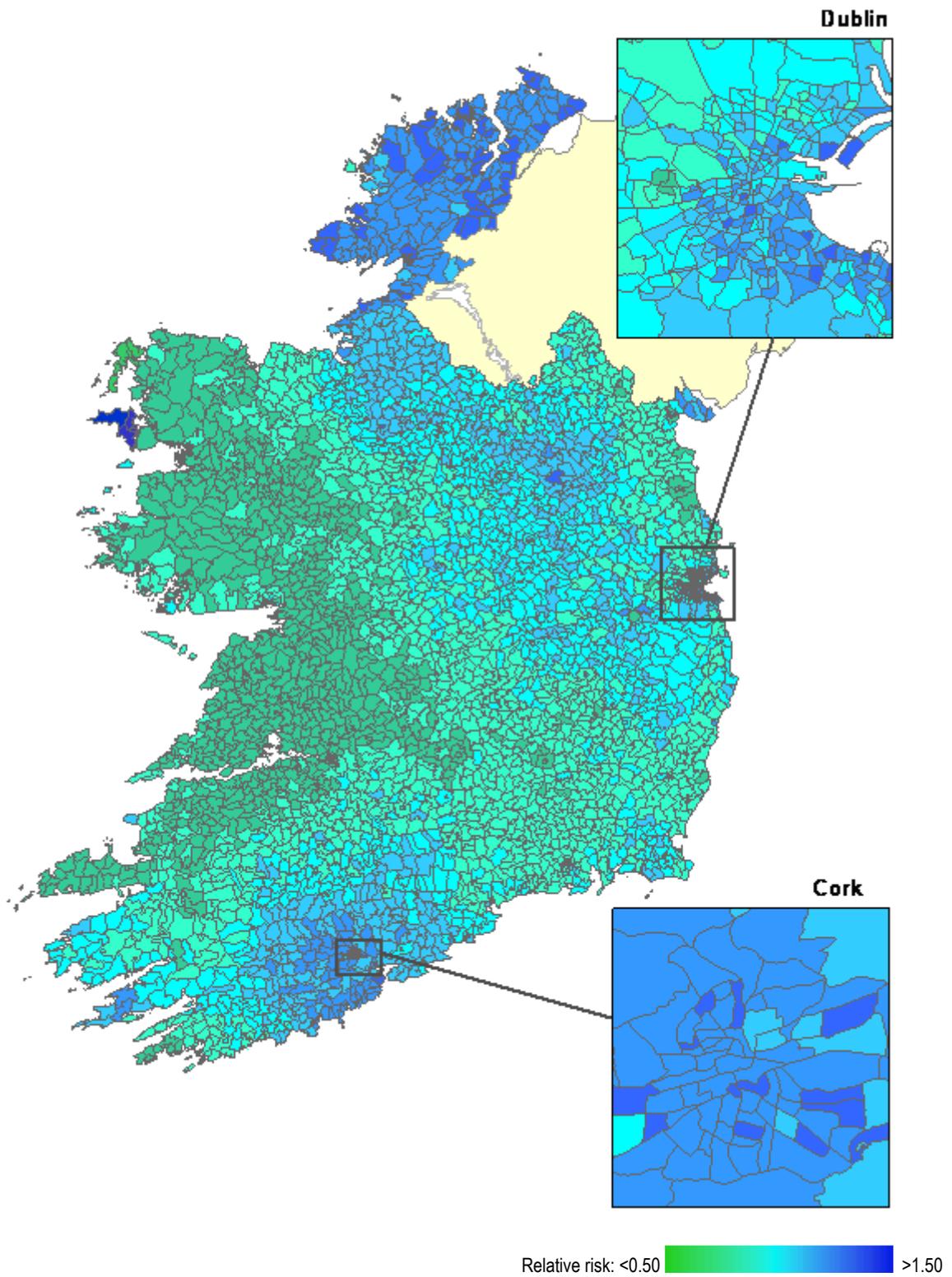
Map 6.1 Colorectal cancer, smoothed relative risks: both sexes



Map 6.2 Colorectal cancer, smoothed relative risks: males



Map 6.3 Colorectal cancer, smoothed relative risks: females



7 Lung cancer

7.1 Summary

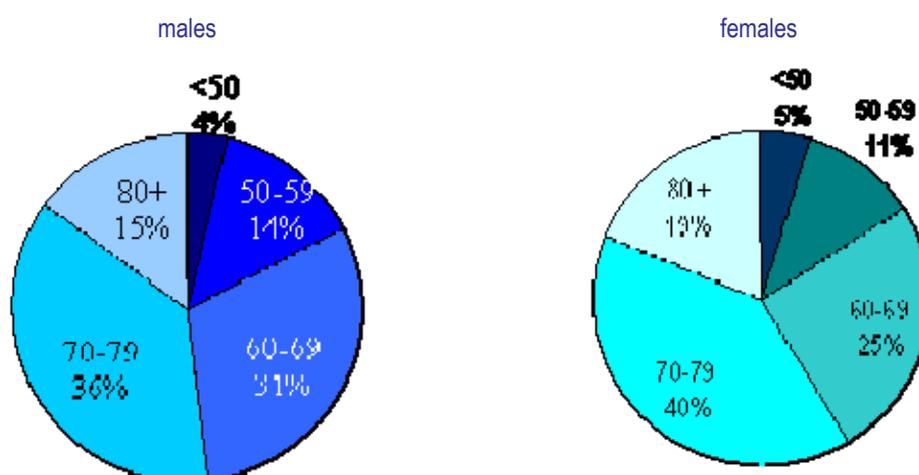
Lung cancer is the third most common cancer in Ireland, accounting for 15% of cancers in men and 9% in women, if non-melanoma skin cancer is excluded (table 7.1). Each year, approximately 1,025 men and 585 women are diagnosed with a lung tumour. In women, the incidence rate rose significantly during 1994 and 2003, by 2.2% per annum, whereas in men it fell slightly (1.0% per annum).

Table 7.1 Summary information for lung cancer in Ireland, 1994-2003

	females	males
% of all new cancer cases	7%	10%
% of all new cancer cases excluding non-melanoma skin cancer	9%	15%
Average number of new cases per year	585	1,025
Average number of deaths per year	541	963
Age standardised incidence rate per 100,000 (European standard population)	29.4	63.4
Estimated annual percentage change in rate 1994-2003	2.2%	-1.0%

The majority of those diagnosed with lung cancer were aged 70 and over (figure 7.1). Less than 5% of cases presented in those aged under 50. Male lung cancer patients were younger on average than females - 48% were under 70, compared to 41% of females.

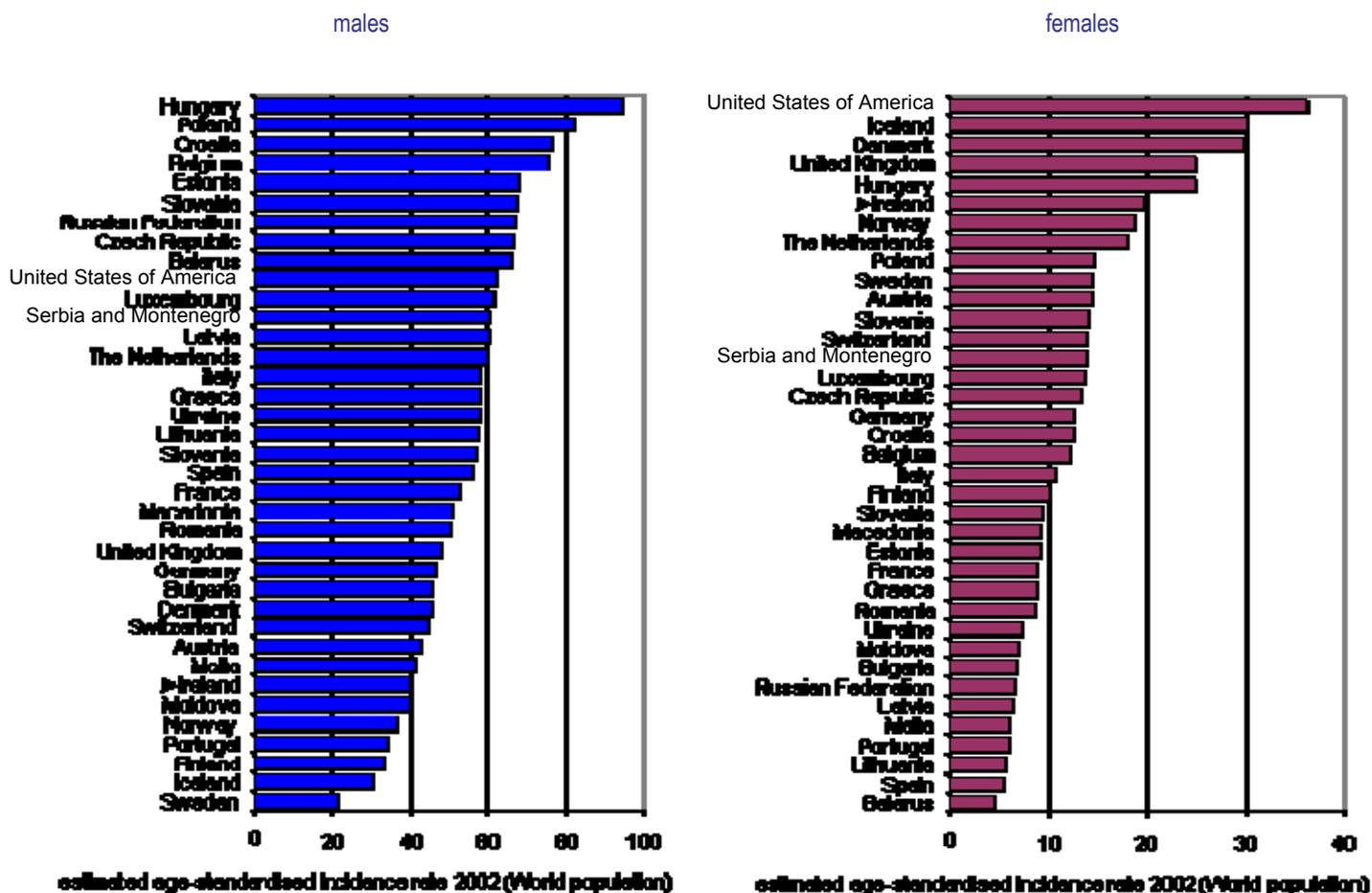
Figure 7.1 Age distribution of lung cancer cases, 1994-2003, males and females



7.2 International variations in incidence

The lung cancer incidence rate in women in Ireland in 2002 was one of the highest in Europe (figure 7.2). In contrast, incidence rates in men were among the lowest. A similar pattern of incidence can be seen in Denmark, the UK and Iceland, while Hungary and the USA have high incidence rates for both sexes. The differences between countries, and between men and women, are almost entirely a result of different trends in tobacco use in different populations (see section 7.3).

Figure 7.2 Estimated incidence rate per 100,000 in 2002 for Europe and USA: lung cancer



Source: GLOBOCAN 2002 (Ferlay et al, 2004)

7.3 Risk factors

Table 7.2 Risk factors for lung cancer, by strength of evidence

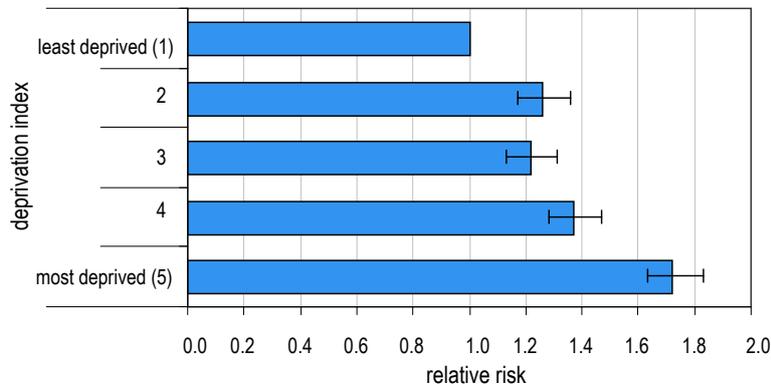
	Increases risk	Decreases risk
<i>Convincing or probable</i>	Tobacco smoking ¹	Fruit ⁵
	Involuntary (passive) smoking ¹	Foods containing carotenoids ^{5,8}
	Asbestos exposure ²	
	Radon exposure ²	
	Ionizing radiation exposure (including X-rays and gamma radiation) ²	
	Family history of lung cancer ^{3,4}	
	Arsenic in drinking water ⁵	
	Beta-carotene supplements (in current smokers) ⁵	
	Low socio-economic status ⁶	
	<i>Possible</i>	Alcohol ⁷
Low body fatness ⁵		Non-starchy vegetables ^{5,10}
		Aspirin and other non-steroidal anti-inflammatory drugs ¹¹

¹ International Agency for Research on Cancer, 2004b; ² US Department of Health and Human Services, 2005; ³ First degree relative(s) with lung cancer; ⁴ Matakidou et al, 2005; ⁵ World Cancer Research Fund / American Institute for Cancer Research, 2007; ⁶ Faggiano et al, 1997; ⁷ International Agency for Research on Cancer, in press; ⁸ carotenoids are found in vegetables, particularly those which are red and orange; ⁹ International Agency for Research on Cancer, 2002; ¹⁰ International Agency for Research on Cancer, 2003; ¹¹ Bosetti et al, 2006

Smoking is the principal cause of lung cancer (table 7.2). In populations with prolonged cigarette use, 90% of lung cancer cases are due to cigarette smoking (International Agency for Research on Cancer, 2004b). Duration of smoking is the strongest determinant of risk among smokers; the earlier the starting age or the longer the period of smoking, the higher the risk. Stopping smoking, at any age but particularly so before middle age, avoids most of the subsequent risk (Peto et al, 2000). Involuntary exposure to tobacco smoke (passive smoking) is a cause of lung cancer in those who have never smoked. Genome-wide association studies have identified a specific candidate locus but it not clear whether this confers susceptibility to lung cancer or to aspects of smoking behaviour (Easton and Eeles, 2008). Lung cancer risk has consistently been found to be higher in those of low socio-economic status, probably reflecting social class variations in tobacco exposure. Recent systematic reviews suggest that increased consumption of fruit and foods containing carotenoids (generally vegetables, particularly those which are red or orange) is associated with decreased lung cancer risk, even after adjusting for smoking status. In contrast, randomised controlled trials suggest that, in smokers, taking beta-carotene supplements is associated with increased disease risk. Various other lifestyle factors (such as alcohol intake, and physical activity) may be related to lung cancer, but the evidence is inconsistent and it is not always possible to rule out the possibility that the findings are due to some residual effect of smoking. The chances of developing lung cancer are increased in those exposed to asbestos, radon, ionizing radiation and arsenic in drinking water.

7.4 Electoral district characteristics and cancer incidence

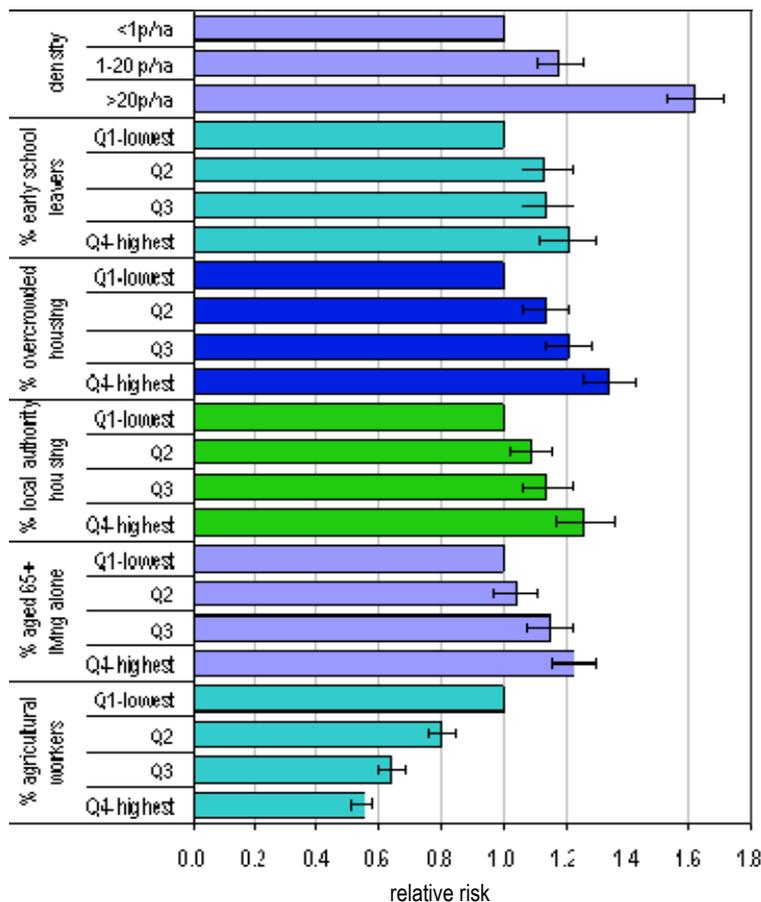
Figure 7.3 Adjusted relative risks of lung cancer by deprivation index: males



Adjusted for population density

Lung cancer incidence in men was strongly associated with the deprivation index of their area of residence (figure 7.3). The risk in areas of highest deprivation was more than 70% higher than in the least deprived (RR=1.72, 95% CI 1.63-1.83). There was no statistically significant difference in incidence between the areas of intermediate deprivation.

Figure 7.4 Adjusted relative risks of lung cancer by area characteristics: males

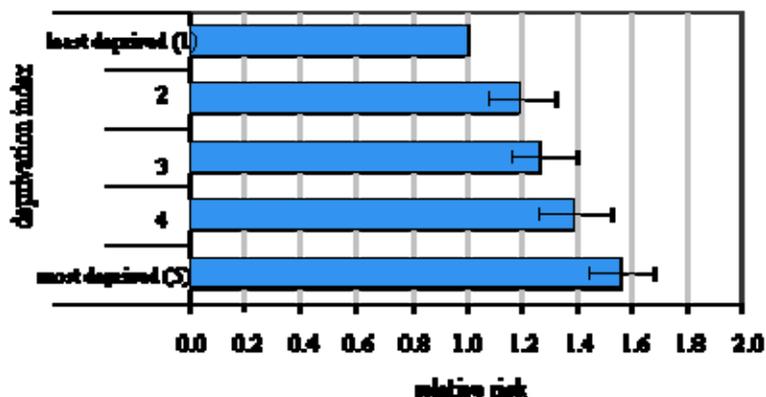


All variables mutually adjusted except % of agricultural workers (not adjusted for density)

There was a strong relationship between lung cancer risk and urban residence in men (figure 7.4). Lung cancer incidence in the most densely populated areas was more than 60% higher than in the least populated areas (RR=1.62, 95% CI 1.53-1.71). As would be expected from this finding, areas with a low percentage of agricultural workers also had a high risk.

Several other area characteristics were also positively associated with higher incidence of lung cancer in men, including a high proportion of early school leavers, more overcrowded housing, more local authority accommodation, and a higher proportion of people over 65 living alone.

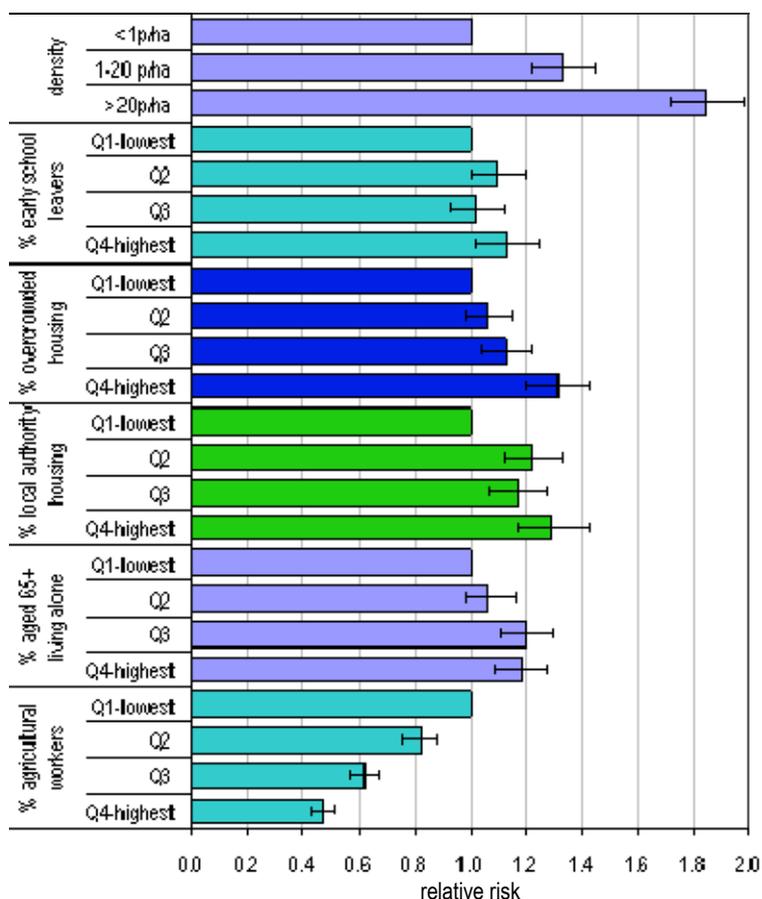
Figure 7.5 Adjusted relative risks of lung cancer by deprivation index: females



Adjusted for population density

As with men, the deprivation index of the area of residence was strongly associated with lung cancer risk in women (figure 7.5). There was a clear linear trend of increasing risk with increasing deprivation. Incidence in most deprived areas was more than 50% higher than that in the least deprived areas (RR=1.56, 95% CI 1.45-1.68).

Figure 7.6 Adjusted relative risks of lung cancer by area characteristics: females



All variables mutually adjusted except % of agricultural workers (not adjusted for density)

Compared to women resident in the most rural areas (<1p/ha), those in most urban areas had almost double the incidence of lung cancer (RR=1.84, 95% CI 1.172-1.98 figure 7.6). A strong reciprocal relationship was seen with the proportion of agricultural workers.

Other area characteristics positively associated with higher lung cancer incidence in women were high proportions of early school leavers, local authority housing, overcrowding and people over 65 living alone.

Socio-economic variation

The composite index of deprivation and several individual measures, including education and housing, were independently associated with lung cancer risk. These variations, and the strong association with population

density, probably reflect geographical and socio-demographic patterns in smoking habits. At the individual level in Ireland, smoking is strongly related to both social class and urban residence (Office of Tobacco Control, 2009).

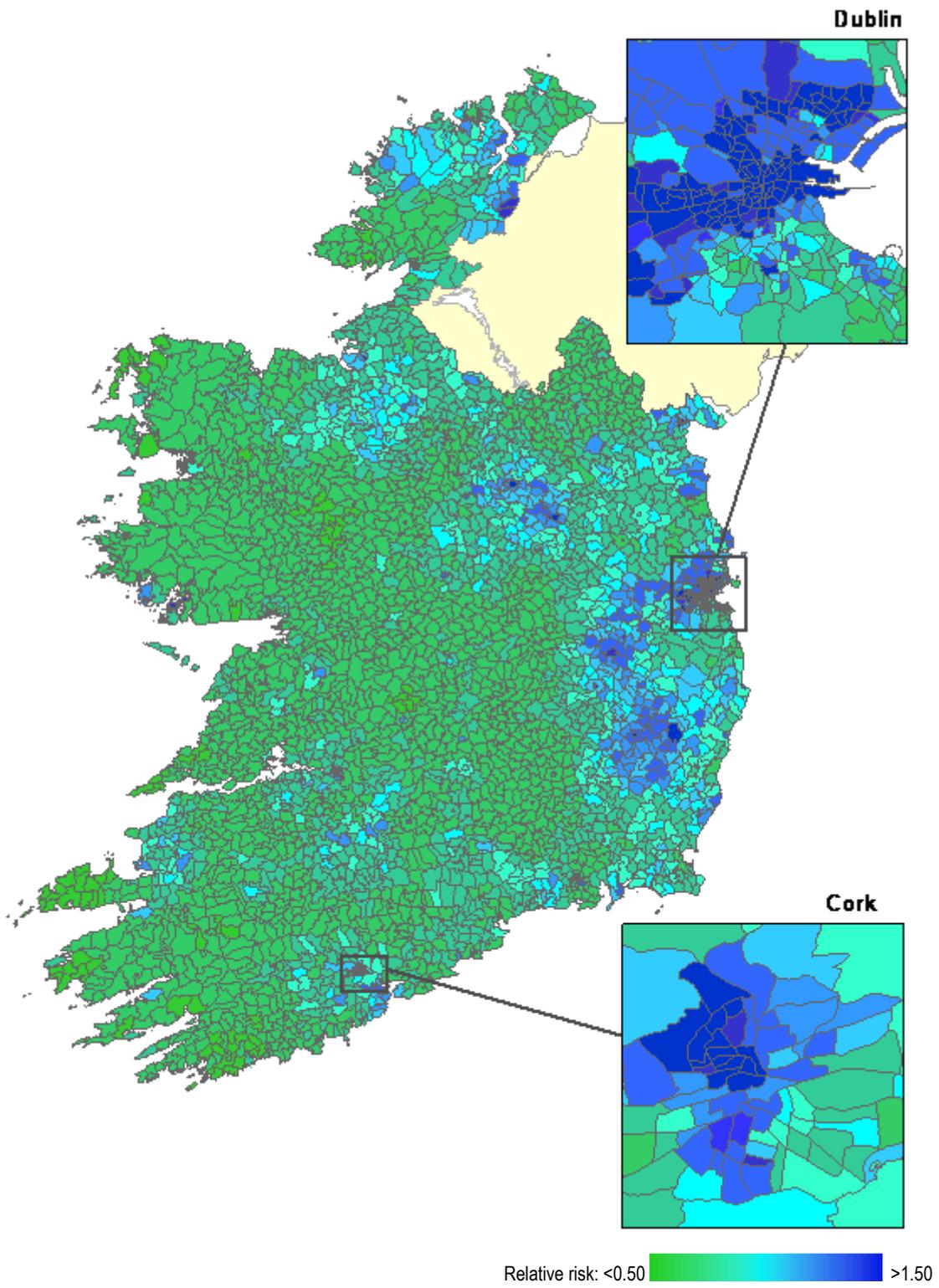
7.5 Mapping and geographical variation

Geographical variation

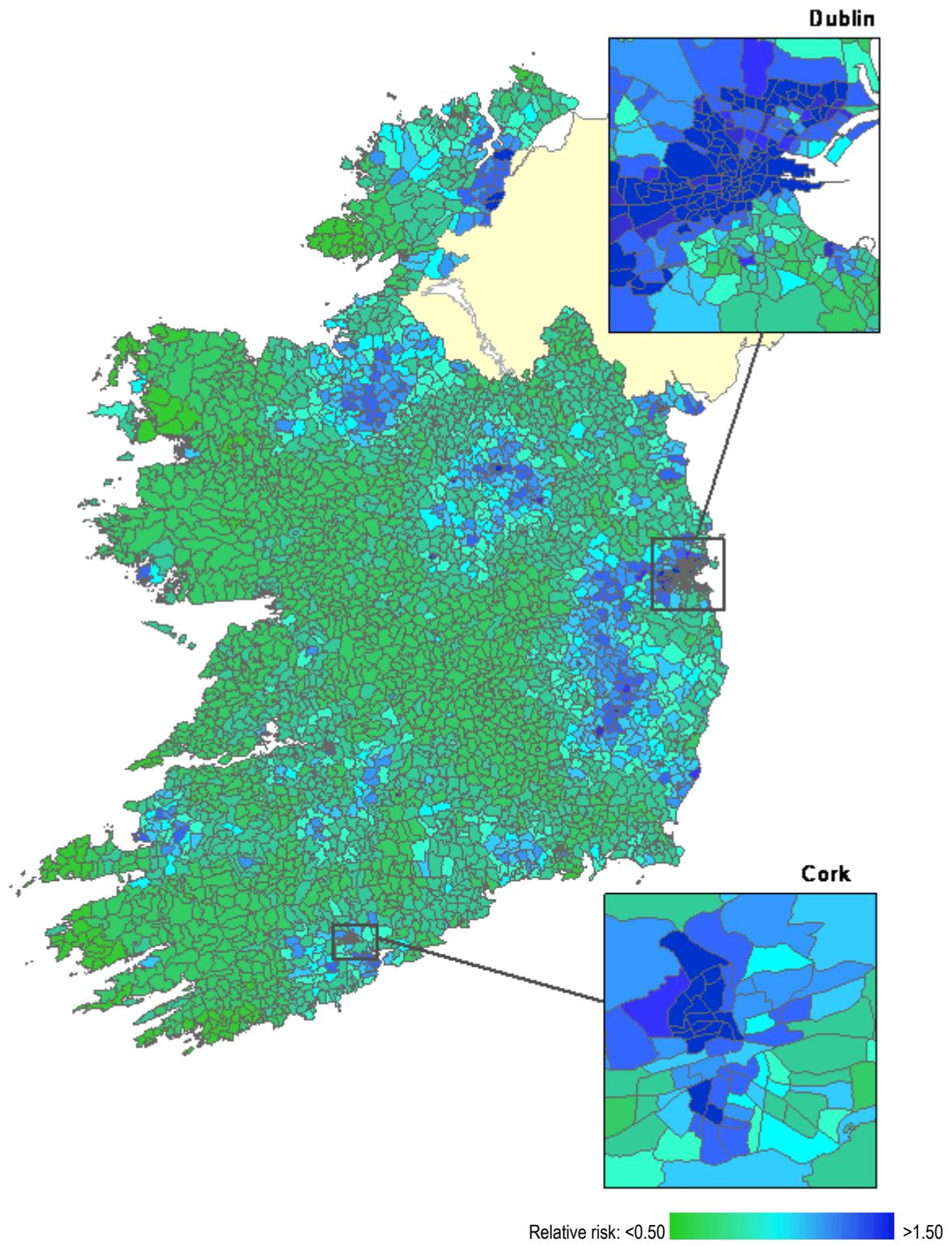
The geographical distribution of lung cancer was similar for men and women; the male pattern predominated when both sexes were combined, due to the higher incidence in men (maps 7.1-7.3). For women, the area of highest incidence was in Leinster, centred on Dublin, with the highest rates in Dublin, Kildare and Wicklow. A much smaller area of high incidence was centred on Cork city. Within Dublin and Cork cities, the areas of highest incidence were in the north and northwest respectively, which contain a larger proportion of areas of higher deprivation. For men, there was a more widespread pattern of high incidence. In addition to high rates in Leinster, there were pockets of high incidence in the northwest - Sligo, Leitrim and Donegal. Within the cities of Cork and Dublin, the pattern was similar to that seen for women.

There was, as would be expected, a correlation with the geographical distribution of levels of current smoking reported in the SLÁN survey (Appendix 1). However, there was little apparent relationship to measures of household income or social class. Although not striking, there were some similarities between the distribution of lung cancer (outwith the main cities) and that of radon levels, at least in the southeast of the country. However, lung cancer incidence was not especially high in the western parts of the country, which had higher predicted percentages of houses with radon levels exceeding 200 Bq/m³ (Appendix 1).

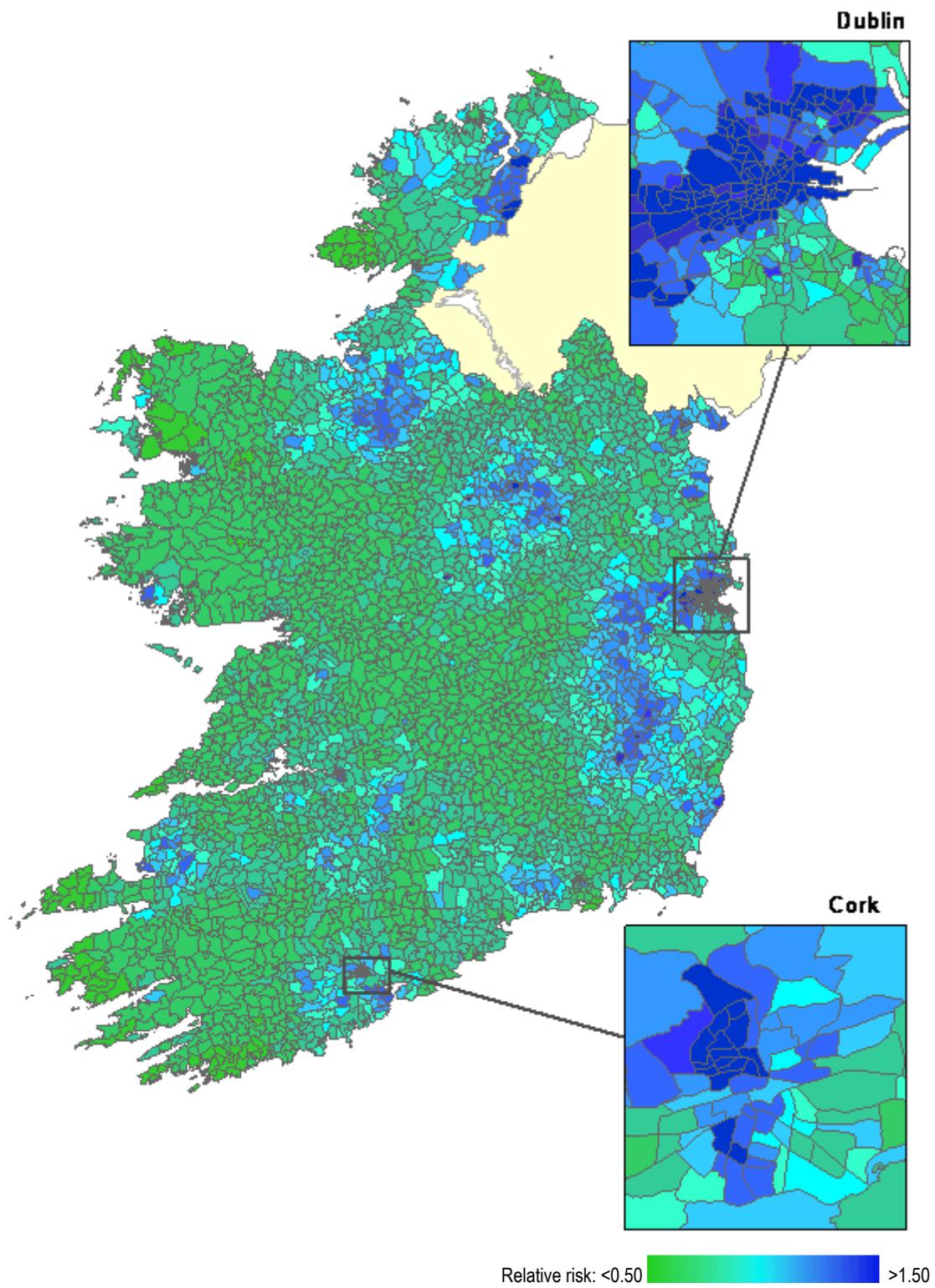
Map 7.1 Lung cancer, smoothed relative risks: both sexes



Map 7.2 Lung cancer, smoothed relative risks: males



Map 7.3 Lung cancer, smoothed relative risks: females



8 Prostate cancer

8.1 Summary

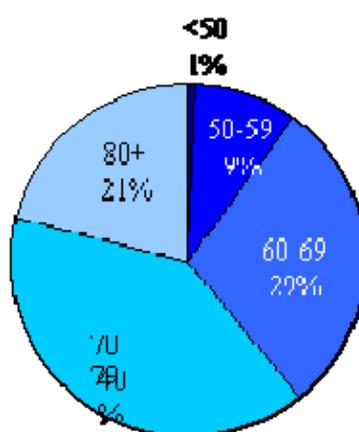
Prostate cancer is the most commonly diagnosed cancer in men in Ireland. When non-melanoma skin cancer is excluded, prostate cancer accounts for 23% of all new cancers in men. Each year, approximately 1,525 men are diagnosed with a prostate tumour. During 1994 and 2003, the incidence of prostate cancer rose faster than that of any other cancer; rates increased by an average of 7.1% annually. This has been driven, in large part, by large increases in the frequency of prostate specific antigen (PSA) testing in Ireland over this period (Drummond et al, 2009a).

Table 8.1 Summary information for prostate cancer in Ireland, 1994-2003

% of all new cancer cases	16%
% of all new cancer cases excluding non-melanoma skin cancer	23%
Average number of new cases per year	1,525
Average number of deaths per year	517
Age standardised incidence rate per 100,000 (European standard population)	94.5
Estimated annual percentage change in rate 1994-2003	7.1%

Prostate cancer is predominantly a disease of older age. Less than 1% of cases present in those aged under 50, while 90% occur in those 70 and older (figure 8.1). Just over one-fifth of cases are diagnosed in men aged 80 years and older.

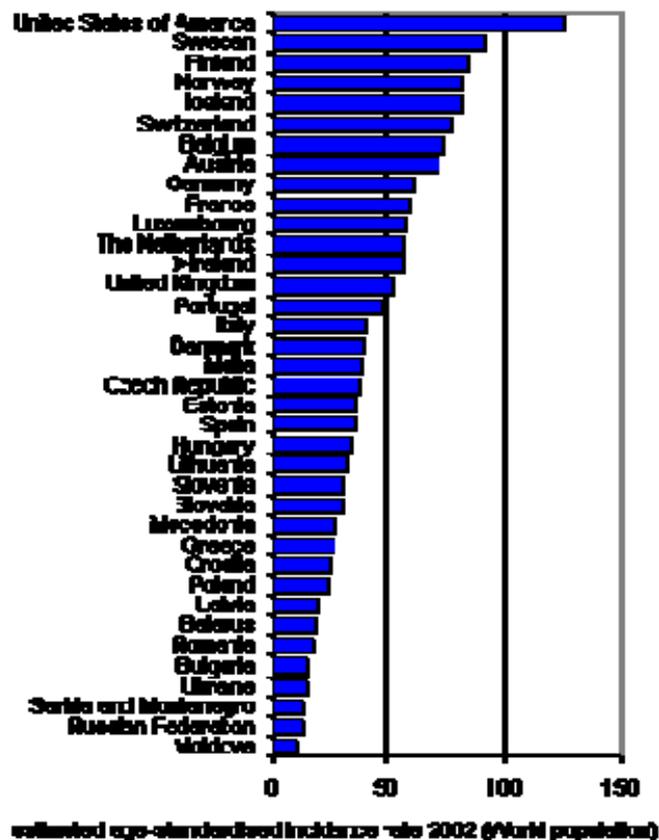
Figure 8.1 Age distribution of prostate cancer cases, 1994-2003



8.2 International variations in incidence

Prostate cancer incidence in Ireland in 2002 was low by western European and US standards, although comparable to the UK and many southern and eastern European countries (figure 8.2). The wide range in incidence rates observed in developed western populations is more likely to be due to differences in the frequency of PSA "screening" in different countries, than to major differences in the underlying disease incidence. It should be noted that the data given here are estimates made by the International Agency for Research on Cancer based on previous years, and, because of the large increase in incidence rate in Ireland, the estimated incidence rate shown is well below the actual 2002 rate.

Figure 8.2 Estimated incidence rate per 100,000 in 2002 for Europe and USA: prostate cancer



Source: GLOBOCAN 2002 (Ferlay et al, 2004)

8.3 Risk factors

Table 8.2 Risk factors for prostate cancer, by strength of evidence

	Increases risk	Decreases risk
<i>Convincing or probable</i>	Family history of prostate cancer ^{1,2}	Foods containing lycopene ^{3,4}
	Diets high in calcium ³	Selenium or foods containing selenium ⁴
<i>Possible</i>	Obesity (aggressive prostate cancer) ⁴	Obesity (non-aggressive prostate cancer) ⁵
		Aspirin and other non-steroidal anti-inflammatory drugs ⁶

¹ First degree relative(s) with prostate cancer; ² Damber and Aus, 2008; ³ lycopene is a carotenoid found in tomatoes and tomato products; ⁴ World Cancer Research Fund / American Institute for Cancer Research, 2007; ⁴ Giovannucci and Michaud, 2007; ⁵ Bosetti et al, 2006

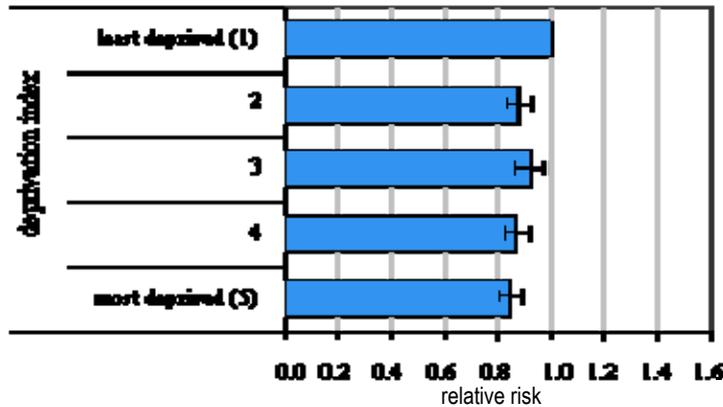
It has long been known that having a first degree relative affected by prostate cancer increases a man's risk of developing the disease. Recently, advances have been made in uncovering the genetic basis underpinning familial risk. Several regions of the genome have been implicated in prostate cancer, but as yet the specific genes involved have not been identified (Easton and Eeles, 2008).

Despite extensive study, relatively little is known about prostate cancer aetiology. The few clearly established risk factors relate to diet (table 8.2). Lycopene is a carotenoid with strong anti-oxidant activities found in tomatoes and tomato products, such as puree, sauce, and soup. There is a substantial amount of evidence that higher levels of intake of lycopene-containing foods and products are associated with decreased prostate cancer risk. The mineral selenium is present in soil and makes its way into vegetables. It is also found in brazil nuts, fish, whole-grains and wheat-germ, and can be taken in the form of dietary supplements. There is reasonably strong evidence to suggest that intake of selenium or selenium-containing foods is inversely associated with prostate cancer. In contrast, prostate cancer risk increases, in a dose-response fashion, with higher dietary calcium intake.

There is some evidence that obesity may be associated with reduced risk of non-aggressive prostate cancer but increased risk of aggressive disease. It has been suggested that this may be due to a detection bias relating to the ability to detect prostate cancer in obese men (Buschemeyer and Freedland, 2007). Meta-analyses suggest the possibility that regular use of aspirin and other non-steroidal anti-inflammatory drugs may be associated with a small reduction in risk, but the results of the individual studies are inconsistent.

8.4 Electoral district characteristics and cancer incidence

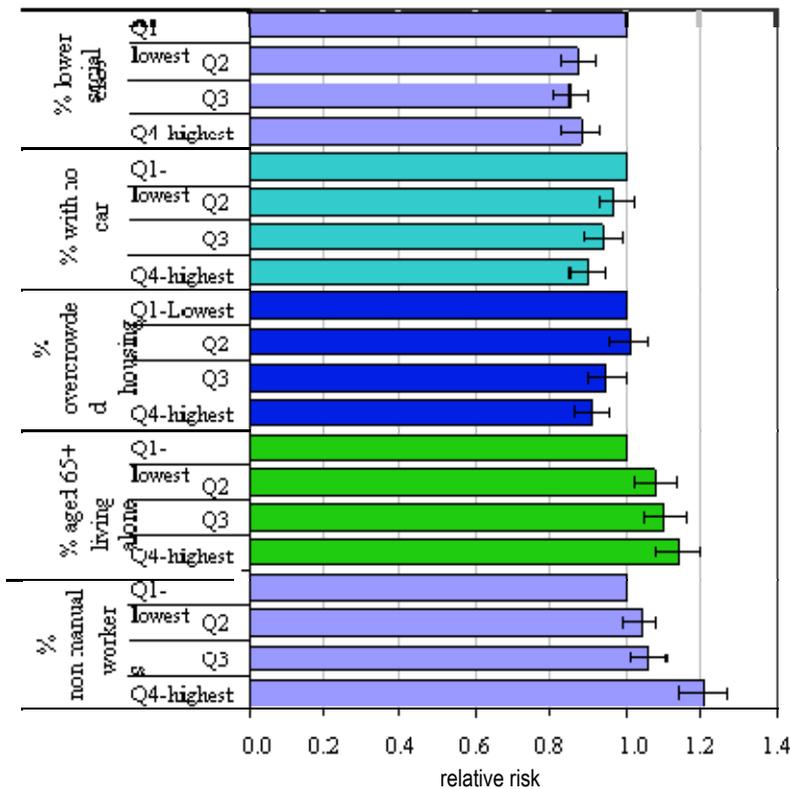
Figure 8.3 Adjusted relative risks of prostate cancer by deprivation index: males



The incidence of prostate cancer was negatively associated with deprivation (figure 8.3). Men living in the most deprived areas were 15% less likely to be diagnosed with prostate cancer than those resident in the least deprived areas (RR=0.85, 95% CI 0.81-0.89).

Adjusted for population density

Figure 8.4 Adjusted relative risks of prostate cancer by area characteristics: males



Incidence of prostate cancer was lower among men resident in areas with a higher proportion of overcrowded housing, individuals in lower social classes and persons who did not own a car (figure 8.4). In contrast, men living in areas with the highest proportion of non-manual workers had 20% higher risk of prostate cancer compared to men in areas with the lowest proportion of non-manual workers.

The risk of prostate cancer increased steadily with an increase in the proportion of people aged 65 or over living alone.

All variables mutually adjusted except % of agricultural workers (not adjusted for density)

Socio-economic variation

The observed inverse association between prostate cancer and a composite area-based measure of socio-economic status has also been seen in England and Wales (Rowan, 2007), Northern Ireland (Donnelly et al, 2009)

and the USA (Liu et al, 2001). The observed associations with various other socio-economic variables are consistent with these findings. In England and Wales, the gap in incidence between the least and most deprived areas has increased over time (Rowan, 2007). These patterns suggest that the socio-economic variations in incidence are an artefact of differences in the frequency of PSA "screening" in different groups of men, although data are lacking to confirm this in Ireland.

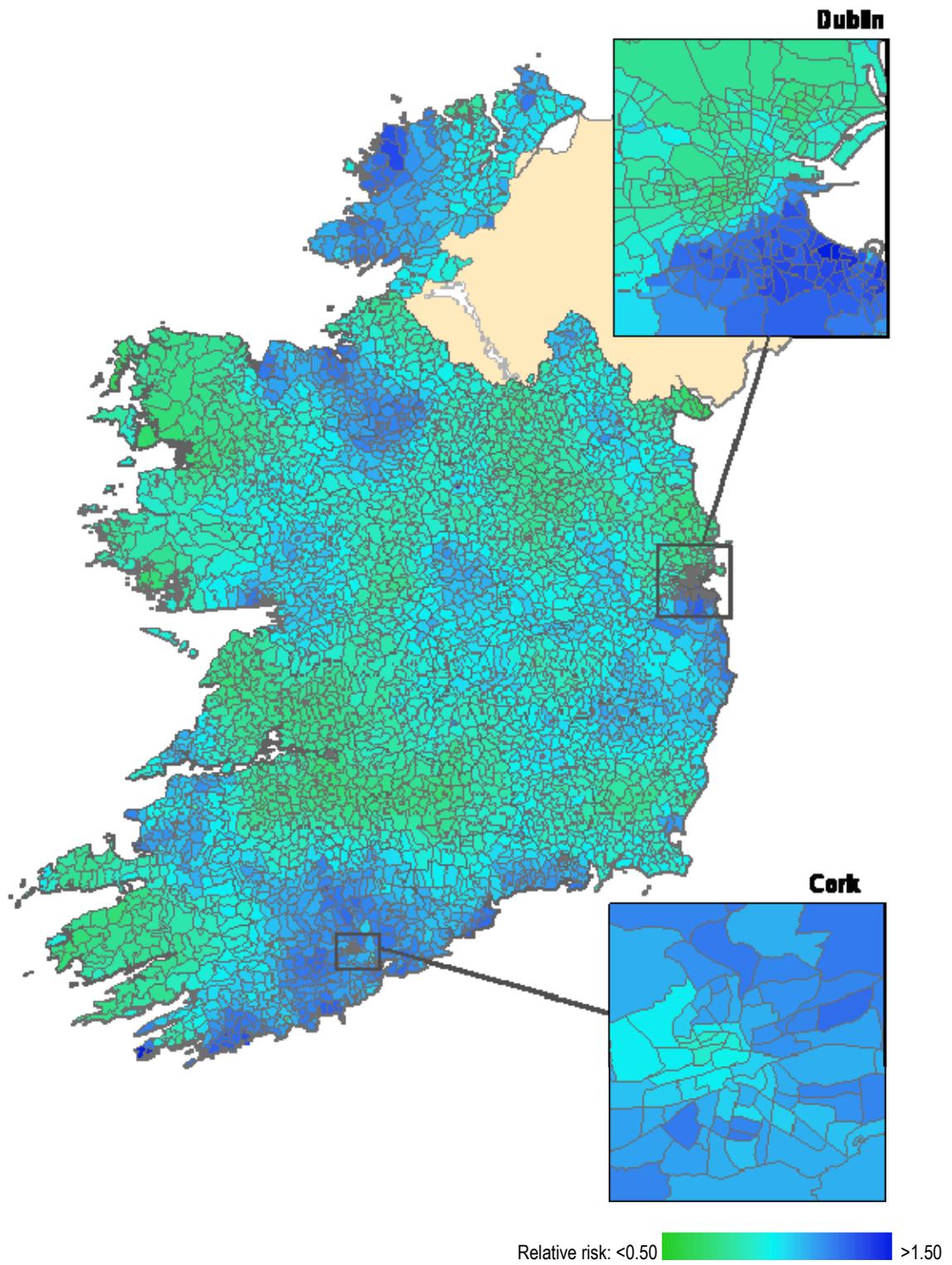
8.5 Mapping and geographical variation

Geographical variation

Prostate cancer incidence was highest around the major urban centres - Dublin, Cork, Waterford and Galway - but, as with breast cancer, not Limerick (map 8.1). Within the two largest cities, there was a very clear divide between the more affluent areas (e.g. south of Dublin), which had a higher incidence, and the rest. There were also distinct areas of higher incidence in the northwest of the country, in Sligo and Donegal.

Looking at the data available from the SLÁN survey (Appendix 1), the distribution of obesity had some similarities with that of prostate cancer incidence, although the closest correspondence seemed to be with levels of private health insurance.

Map 8.1 Prostate cancer, smoothed relative risks: males



9 Stomach cancer

9.1 Summary

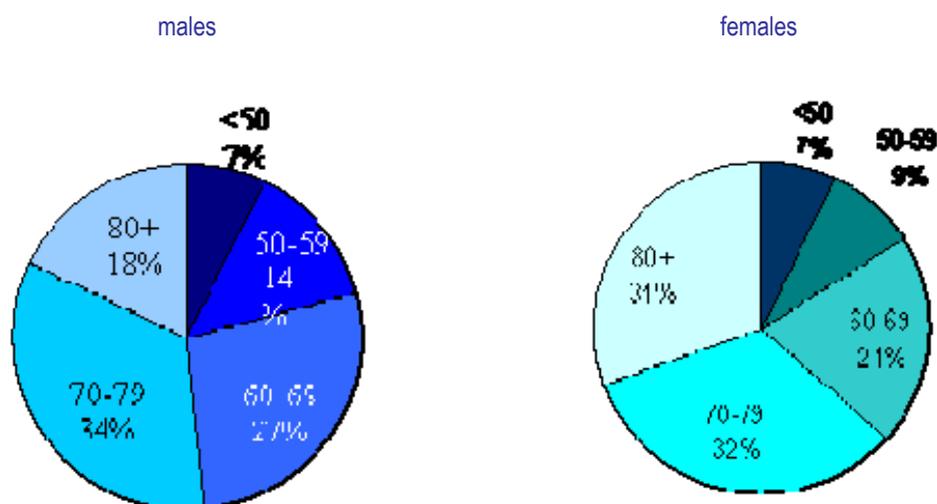
Stomach cancer ranks seventh in terms of the most common cancers in Ireland, accounting for 4.1% of all malignant neoplasia in men and 2.8% in women, when non-melanoma skin cancer is excluded (table 9.1). Each year, approximately 292 men and 183 women are diagnosed with a stomach tumour. During 1994-2003, incidence rates fell in both sexes.

Table 9.1 Summary information for stomach cancer in Ireland, 1994-2003

	females	males
% of all new cancer cases	2.0%	2.9%
% of all new cancer cases excluding non-melanoma skin cancer	2.8%	4.1%
Average number of new cases per year	183	292
Average number of deaths per year	218	366
Age standardised incidence rate per 100,000 (European standard population)	8.7	18.1
Estimated annual percentage change in rate 1994-2003	-1.7%	-3.0%

More than half of all men and women with stomach cancer were aged over 70 at diagnosis - 63% of women and 52% of men (figure 9.1). The higher proportion of older women probably reflects their higher life expectancy. Only 7% of cases present in those aged under 50.

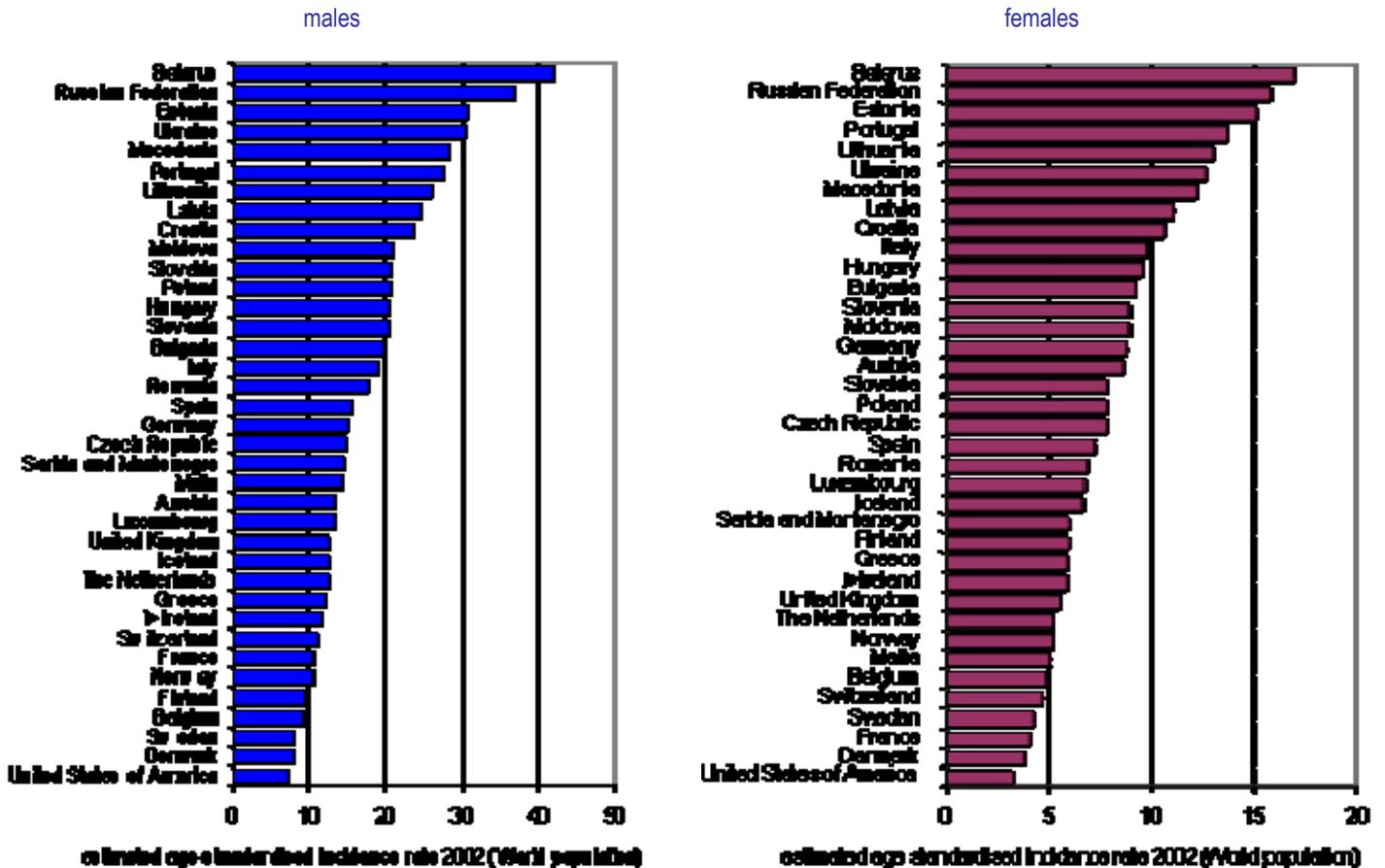
Figure 9.1 Age distribution of stomach cancer cases, 1994-2003, males and females



9.2 International variations in incidence

Stomach cancer incidence in both men and women in Ireland in 2002 is in the lower half of rates across western Europe (figure 9.2). Rates in Ireland were similar to those in the UK for both sexes. The rate in both men and women was lower in the USA than in any European country.

Figure 9.2 Estimated incidence rate per 100,000 in 2002 for Europe and USA: stomach cancer



Source: GLOBOCAN 2002 (Ferlay et al, 2004)

9.3 Risk factors

Table 9.2 Risk factors for stomach cancer, by strength of evidence

	Increases risk	Decreases risk
<i>Convincing or probable</i>	<i>Helicobacter pylori</i> infection ¹	Non-starchy vegetables, particularly green/yellow vegetables or allium vegetables ^{3,6,7}
	Tobacco smoking ²	Fruit ^{3,6}
	Salt, salted and salty foods, or salt preserved foods ³	Refrigeration ⁸
	Low socio-economic status ⁴	
<i>Possible</i>	Alcohol ⁵	Aspirin and other non-steroidal anti-inflammatory drugs ⁹

¹ *Helicobacter* and Cancer Collaborative Group, 2001; ² International Agency for Research on Cancer, 2004b; ³ World Cancer Research Fund / American Institute for Cancer Research, 2007; ⁴ Faggiano et al, 1997; ⁵ International Agency for Research on Cancer, in press; ⁶ International Agency for Research on Cancer, 2003; ⁷ allium vegetables include garlic, onions and leeks; ⁸ World Cancer Research Fund / American Institute for Cancer Research, 1997; ⁹ Bosetti et al, 2006

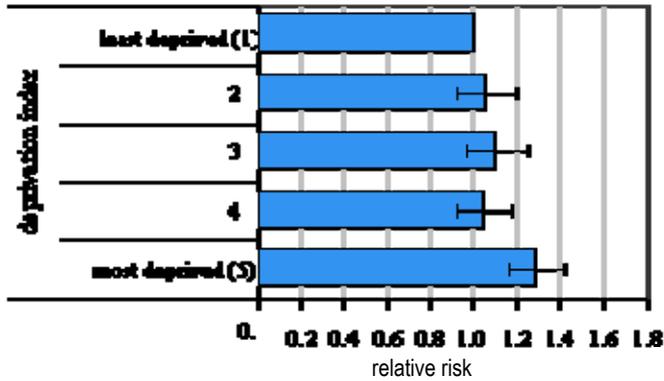
Risk factors for stomach cancer are summarised in table 9.2. *Helicobacter pylori* (*H pylori*) is a bacterium that lives in the stomach and causes inflammation and ulcers. Although the source of *H pylori* infection is not known, infection is common. Surveys in Ireland suggest a prevalence of 40-50% (Murray et al, 1997, Buckley et al, 1998). The risk of stomach cancer is six-fold higher in those with *H pylori* infection than in those without it (*Helicobacter* and Cancer Collaborative Group, 2001), and it has been suggested that it may be a necessary (but not sufficient) cause of tumours arising in the distal region of the stomach (International Agency for Research on Cancer, 1994).

Smoking is firmly established as a cause of stomach cancer and risk increases with duration of smoking and number of cigarettes smoked. Those with low socio-economic status have increased risk of stomach cancer, probably, in part, reflecting variations in tobacco use by social class.

Other than these factors, the main risk factors are related to food and food preservation. There is substantial and consistent evidence that higher intakes of salt, salty foods or foods preserved in salt are associated with increased risk. Risk is reduced in individuals with higher intakes of fruit and non-starchy vegetables, particularly green/yellow vegetables and those of the allium family. More than 10 studies have reported a significant reduction in disease risk with use of refrigeration. However, it is thought that the association is not due to refrigeration *per se* but rather is a consequence of other factors related to refrigerator use, such as lower intake of foods preserved with salt, or higher intake of fresh perishable foods (e.g. vegetables and fruit) (World Cancer Research Fund / American Institute for Cancer Research, 2007). While there are some suggestions that increased consumption of alcohol may be associated with increased risk of stomach cancer, most studies have not adequately controlled for *H pylori* infection or other aspects of diet (International Agency for Research on Cancer, in press).

9.4 Electoral district characteristics and cancer incidence

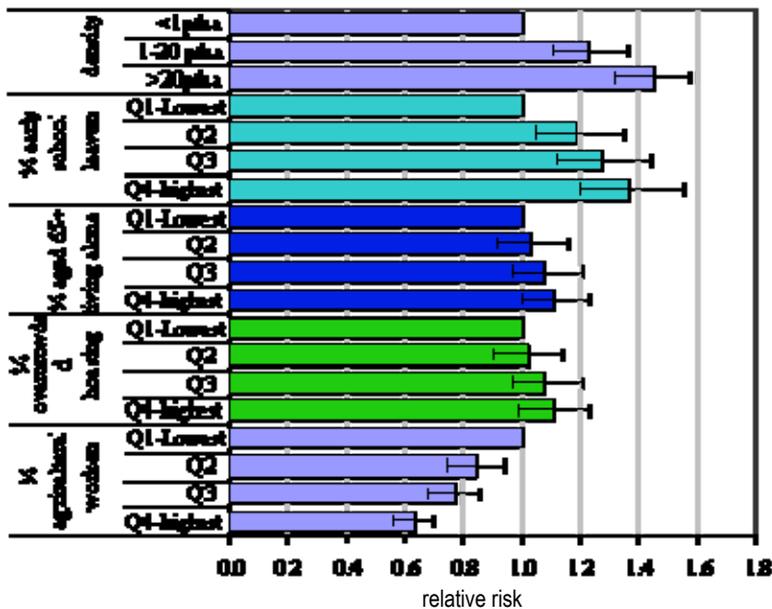
Figure 9.3 Adjusted relative risks of stomach cancer by deprivation index: males



The deprivation index of the area of residence was significantly associated with stomach cancer incidence in men (figure 9.3). Incidence was almost 30% higher in the most deprived, compared to the least deprived, areas (RR=1.28, 95% CI 1.16,1.42).

Adjusted for population density

Figure 9.4 Adjusted relative risks of stomach cancer by area characteristics: males



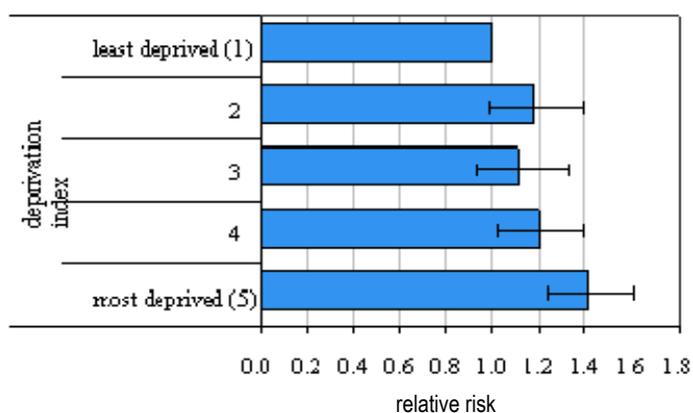
As with several other cancer sites, incidence of stomach cancer in men was higher in more densely populated areas (RR most vs least populated areas= 1.45, 95% CI = 1.32-1.58) and lower where there was a high proportion of agricultural workers (figure 9.4).

Consistent with the relationship to deprivation, there was a trend of increasing risk with an increasing proportion of early school leavers. A similar, but less strong, relationship was also seen with overcrowding.

Stomach cancer incidence in men was also slightly higher in areas with a higher proportion of persons aged 65 and over who were living alone.

All variables mutually adjusted except % of agricultural workers (not adjusted for density)

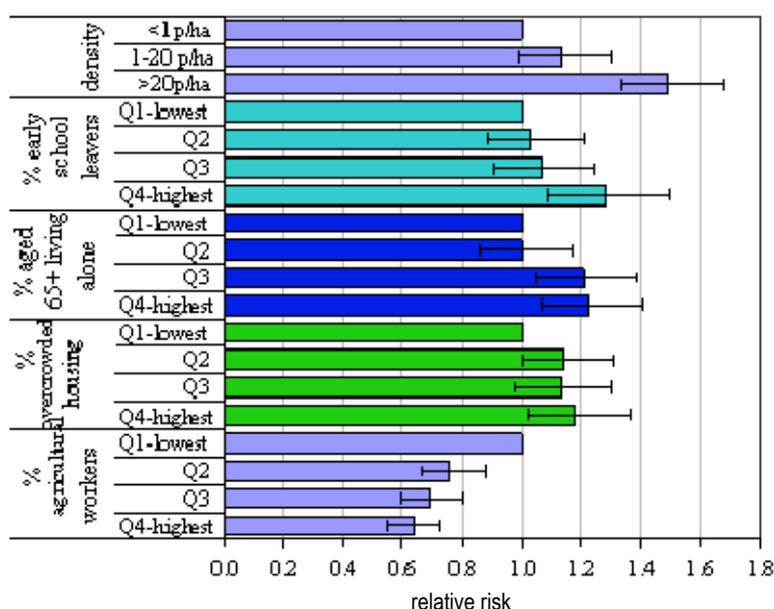
Figure 9.5 Adjusted relative risks of stomach cancer by deprivation index: females



Adjusted for population density

As for men, the deprivation index of the area of residence was associated with stomach cancer incidence in women (figure 9.5). Women who lived in the most deprived areas had a 40% higher risk of stomach cancer than women who lived in the least deprived areas (RR=1.42, 95% CI 1.24-1.61).

Figure 9.6 Adjusted relative risks of stomach cancer by area characteristics: females



All variables mutually adjusted except % of agricultural workers (not adjusted for density)

As for men, there was a strong association between population density and stomach cancer in women. The relative risk in the most densely populated, compared to the least densely populated, areas was 1.49 (95% CI 1.33-1.68; figure 9.6).

Positive associations were also seen with the proportion of early school leavers, the proportion of overcrowded homes, and the proportion of those aged 65 and over living alone.

Incidence decreased with an increase in the proportion of agricultural workers in an area.

Socio-economic variation

The factors associated with elevated stomach cancer risk were similar for women and men; in both sexes there was an association with deprivation, the proportion of early school leavers and of people 65 and over living alone; and a stronger association with population density. The magnitude of the observed associations with population density and the various socio-economic variables were stronger than those seen for most other cancer sites. As for lung cancer, these patterns probably reflect, at least in part, geographical and social class variations in smoking patterns in Ireland (Office of Tobacco Control, 2009).

9.5 Mapping and geographical variation

Geographical variation

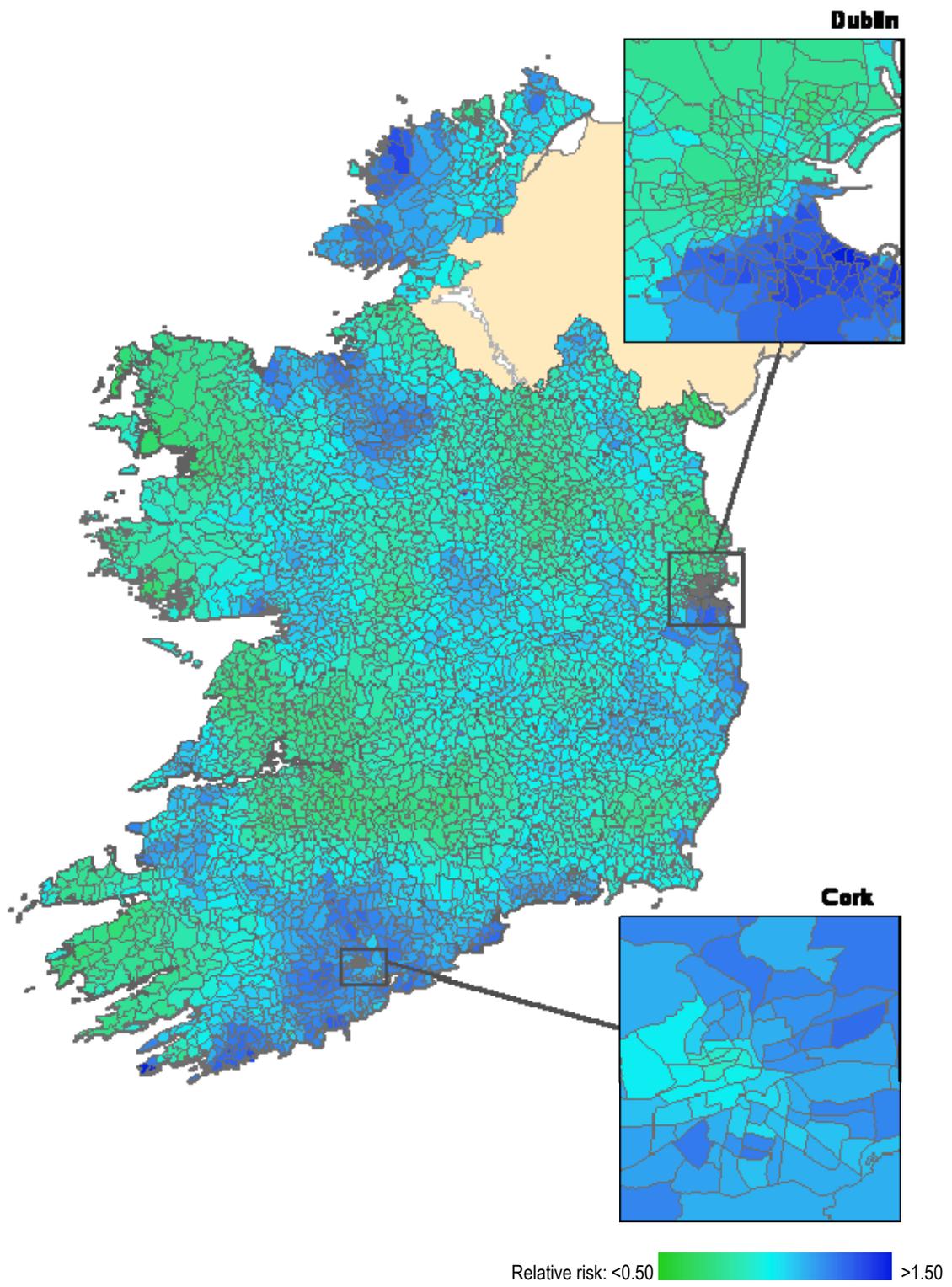
Stomach cancer showed one of the strongest patterns of geographical clustering (map 9.1), with incidence highest in two clearly defined areas, one stretching across the northeast, from Dublin through Louth, Monaghan and Cavan, and the other in south Donegal. In Dublin city, there was a very clear division between the south and southeast of the city, which had a low incidence, and the north and west where incidence was high. The overall incidence was low in the city of Cork, but higher in the northwest of the city.

The pattern of distribution was quite similar for men and women (maps 9.2 and 9.3) although the area of high was less widespread in the northeast for women. Westmeath, northern Offaly and Kildare had a higher risk in men but not in women.

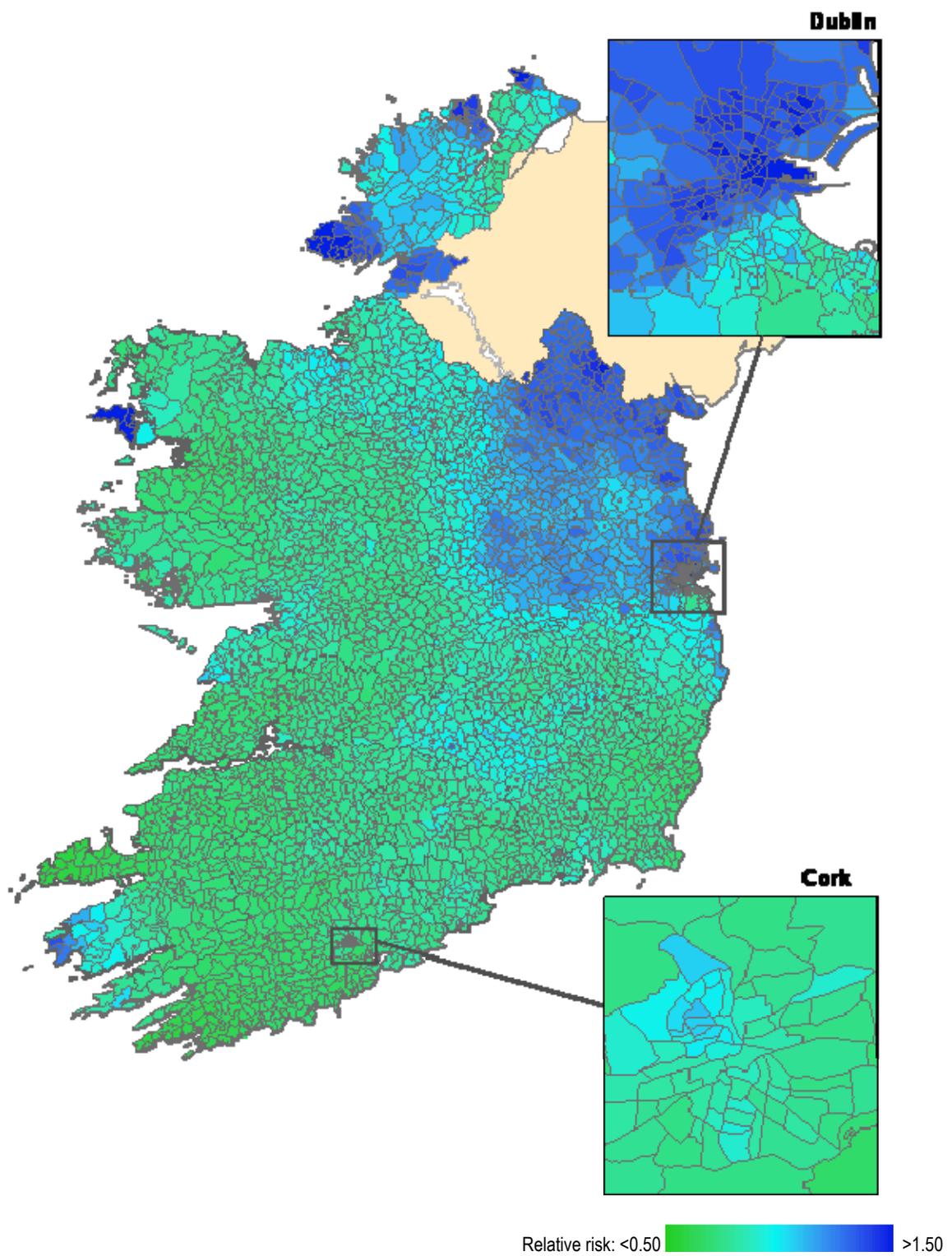
It would be interesting to know whether the areas of higher incidence in the north extend into Northern Ireland. To date, incidence rates for Northern Ireland have only been mapped at the level of district councils (Donnelly et al, 2009). Although it is more difficult to see clear geographical patterns in data at this level, there are some clear areas of higher incidence in the North, specifically around Belfast, and areas close to the border in the south (Newry) and northwest (Derry, Limavady, and Strabane).

There were some similarities between the pattern of incidence in Ireland and the geographical distribution of levels of current smoking reported in the SLÁN survey (Appendix 1), although the specific areas of highest stomach cancer incidence and smoking prevalence did not entirely correspond.

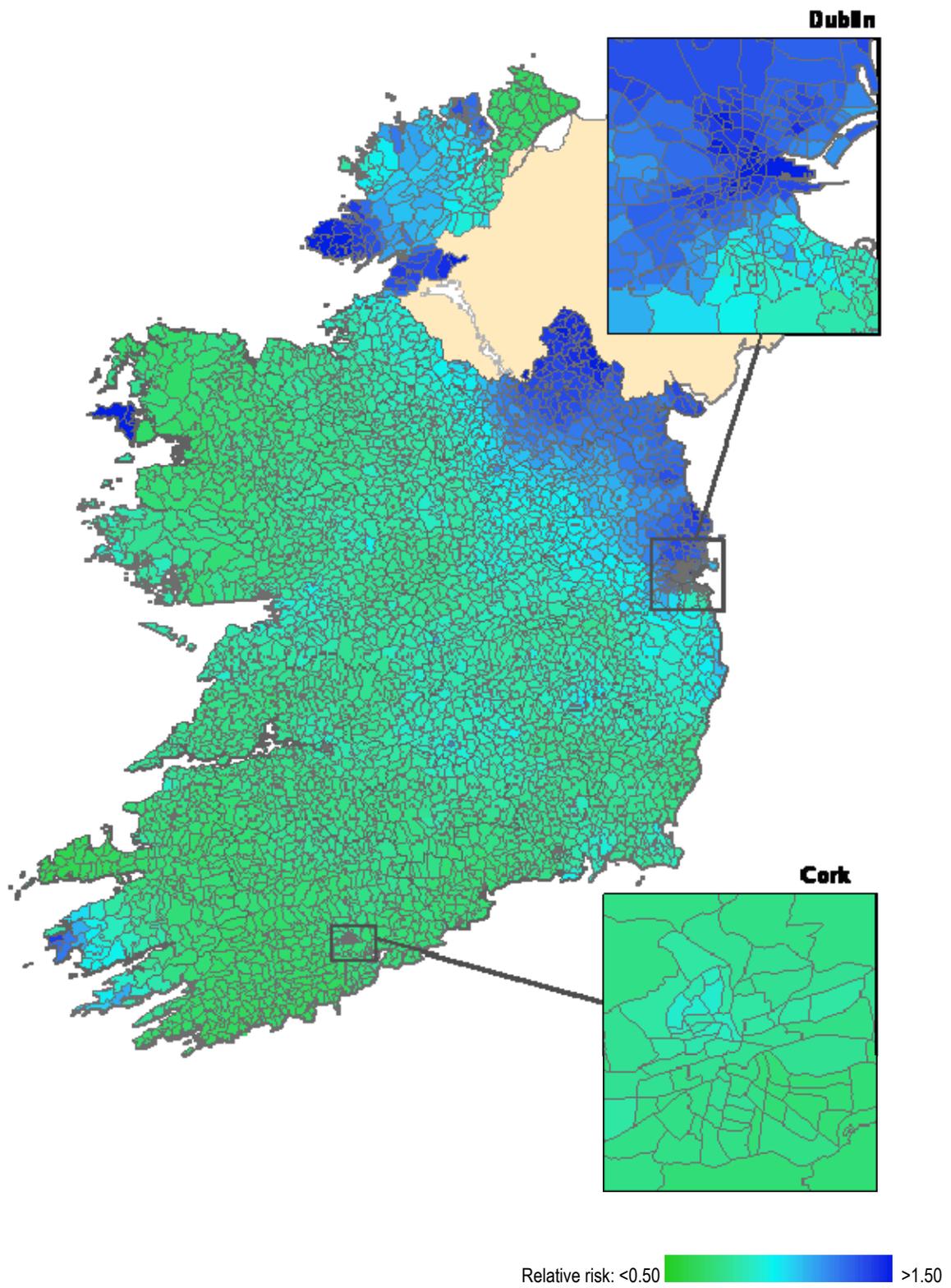
Map 9.1 Stomach cancer, smoothed relative risks: both sexes



Map 9.2 Stomach cancer, smoothed relative risks: males



Map 9.3 Stomach cancer, smoothed relative risks: females



10 Bladder cancer

10.1 Summary

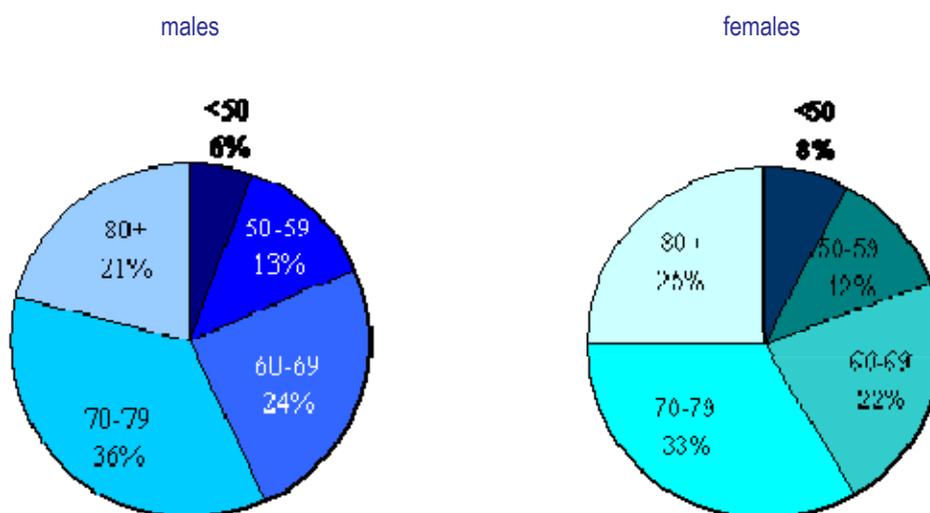
Bladder cancer is the eighth most common malignant cancer in Ireland, accounting for 3.5% of all malignant neoplasia, 4.7% in males and 2.0% in females (table 10.1). Each year, approximately 366 men and 148 women are diagnosed with a bladder tumour. Incidence rates fell between 1994 and 2003 by 1.3% and 2.4% per annum in women and men respectively.

Table 10.1 Summary information for bladder cancer in Ireland, 1994-2003

	females	males
% of all new cancer cases	1.5%	3.3%
% of all new cancer cases excluding non-melanoma skin cancer	2.0%	4.7%
Average number of new cases per year	132	331
Average number of deaths per year	53	112
Age standardised incidence rate per 100,000 (European standard population)	6.6	20.6
Estimated annual percentage change in rate 1994-2003	-1.3%	-2.4%

Bladder cancer is a disease of older patients - 58% of women and 57% of men are aged over 70 at diagnosis (figure 10.1), while only around 6-8% of cases present in those aged under 50. The age distributions in men and women are similar.

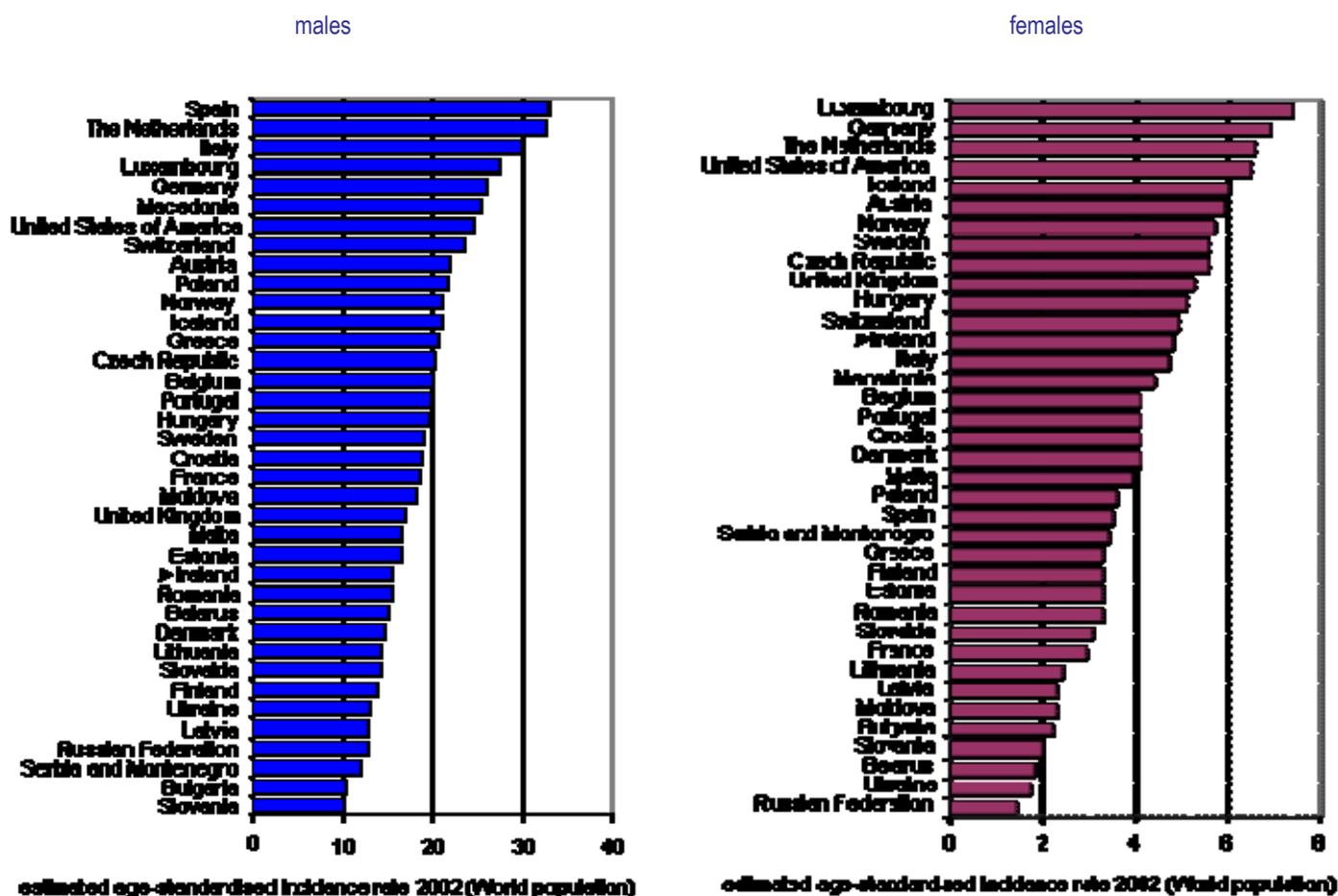
Figure 10.1 Age distribution of bladder cancer cases, 1994-2003, males and females



10.2 International variations in incidence

Bladder cancer incidence in men in Ireland is among the lowest in western Europe (figure 10.2), while that in women is in the mid-range. The rates for both men and women were similar to, but a little lower, than those in the UK. However, international comparisons of bladder cancer rates are made difficult by inconsistencies in the coding and classification of these cancers.

Figure 10.2 Estimated incidence rate per 100,000 in 2002 for Europe and USA: bladder cancer



Source: GLOBOCAN 2002 (Ferlay et al, 2004)

10.3 Risk factors

Table 10.2 Risk factors for bladder cancer, by strength of evidence

	Increases risk	Decreases risk
<i>Convincing or probable</i>	Tobacco smoking ¹	
	Various occupations and employment in particular industries and product manufacture ^{2,3}	
	Occupational exposure to aromatic amines ^{3,4}	
<i>Possible</i>	Arsenic and disinfection by-products in drinking water ^{5,6}	
	Type II diabetes ⁷	

¹ International Agency for Research on Cancer, 2004b; ² Reulen et al, 2008; ³ Scélo and Brennan, 2007; ⁴ International Agency for Research on Cancer, 1987; ⁵ Villanueva et al, 2004; ⁶ World Cancer Research Fund / American Institute for Cancer Research, 2007; ⁷ Larsson et al, 2006

Tobacco smoking is the major known cause of bladder cancer (table 10.2) and it has been estimated that two-thirds of all cases in men, and one-third in women, are due to smoking (Brennan et al, 2000, Brennan et al, 2001). The risk of developing bladder cancer increases with duration of cigarette smoking and number of cigarettes smoked (International Agency for Research on Cancer, 2004b). Risk is also increased in those who smoke pipes or cigars, but do not smoke cigarettes (Pitard et al, 2001). Stopping smoking results in an immediate decrease in risk (Scélo and Brennan, 2007).

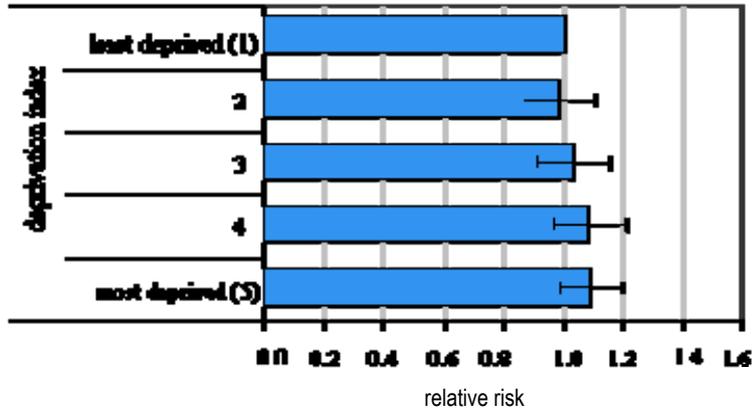
A range of occupations (including mining, bus driving, motor mechanic, blacksmith, machine setter, hairdressing, etc) and employment in various industries or in manufacturing of specific products (including aluminium production and magenta manufacture) have been positively associated with bladder cancer risk. As regards specific exposures, the most consistent evidence relates to aromatic amines, in particular 2-naphthylamine and 4-aminobiphenyl, which are used in the dyeing and rubber industries; workers exposed to these are at increased risk of the disease.

Other than smoking and occupational exposures, the factors involved in bladder cancer aetiology are largely unknown. Positive associations have been reported between volume of tap water consumed and bladder cancer risk (Villanueva et al, 2006). This may be due to increased intake of carcinogenic chemicals contained in the water, such as arsenic (International Agency for Research on Cancer, 2004a) or disinfection by-products (e.g. trihalomethanes), but the results of studies are not consistent.

Individuals with type II diabetes may have a modest increased risk of developing bladder cancer.

10.4 Electoral district characteristics and cancer incidence

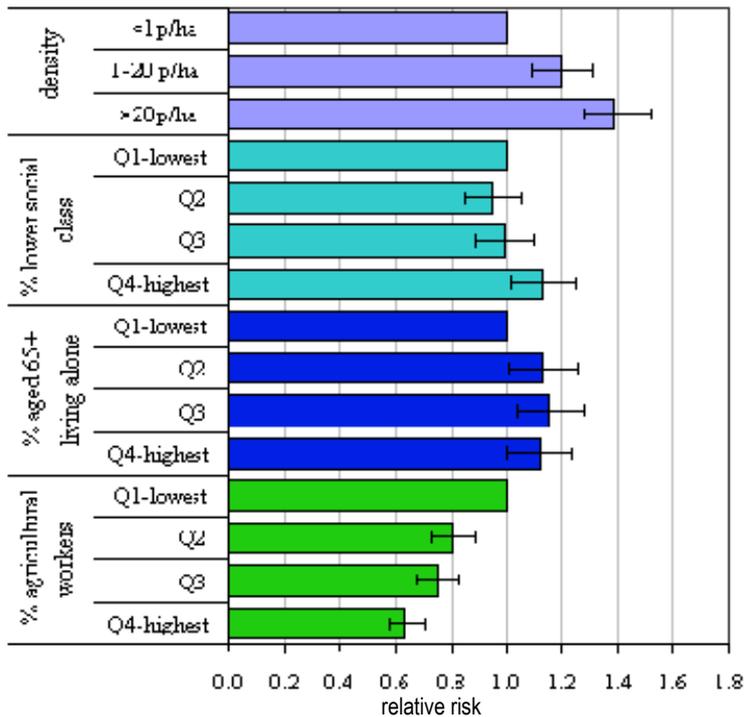
Figure 10.3 Adjusted relative risks of bladder cancer by deprivation index: males



The most deprived areas had a slightly raised risk of bladder cancer in men compared to the least deprived (figure 10.3), but this was not statistically significant.

Adjusted for population density

Figure 10.4 Adjusted relative risks of bladder cancer by area characteristics: males

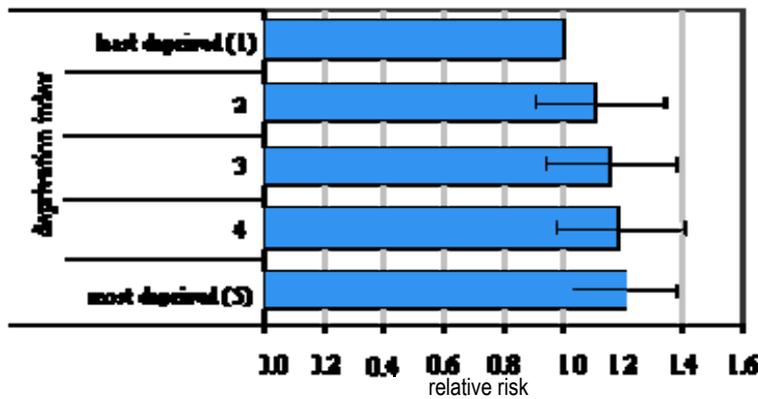


Bladder cancer incidence was strongly associated with population density (figure 10.4). Urban areas (>20p/ha) had a 40% higher risk of bladder cancer than the least densely populated areas (RR=1.39, 95% CI 1.28-1.52). Consistent with this, a higher percentage of agricultural workers was associated with a lower risk of bladder cancer.

Of the other socio-demographic variables, only the percentage in the lowest social class and the percentage of persons aged 65+ living alone were associated with elevated risk. Both of these associations were weak.

All variables mutually adjusted except % of agricultural workers (not adjusted for density)

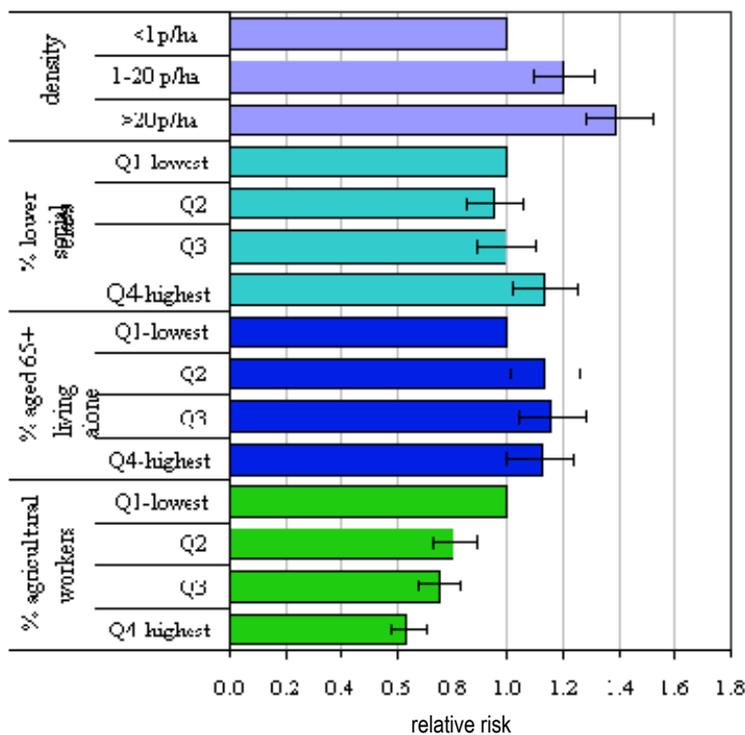
Figure 10.5 Adjusted relative risks of bladder cancer by deprivation index: females



Women living in the most deprived areas had a significantly increased risk of bladder cancer compared to the least deprived (RR=1.20, 95% CI 1.03-1.39; figure 10.5).

Adjusted for population density

Figure 10.6 Adjusted relative risks of bladder cancer by area characteristics: females



As with males, population density and the percentage of agricultural workers were strongly associated with bladder cancer incidence in women (figure 10.6). High frequency of lower social class was associated with a raised risk, compared to low frequency (RR=1.19, 95% CI 1.01-1.40).

There was a weak relationship between incidence and the proportion of people aged 65+ and living alone.

All variables mutually adjusted except % of agricultural workers (not adjusted for density)

Socio-economic variation

The associations between area characteristics and bladder cancer incidence were identical for men and women - a strong relationship to urban residence and a much weaker relationship to social class and to the proportion of elderly living alone. In England also, only a very modest association between bladder cancer and deprivation is

apparent (National Cancer Intelligence Network, 2008). Therefore, although tobacco consumption is the best established risk factor, the links to deprivation/socio-economic status appear to be much weaker than for lung cancer. This suggests that other risk factors must be important.

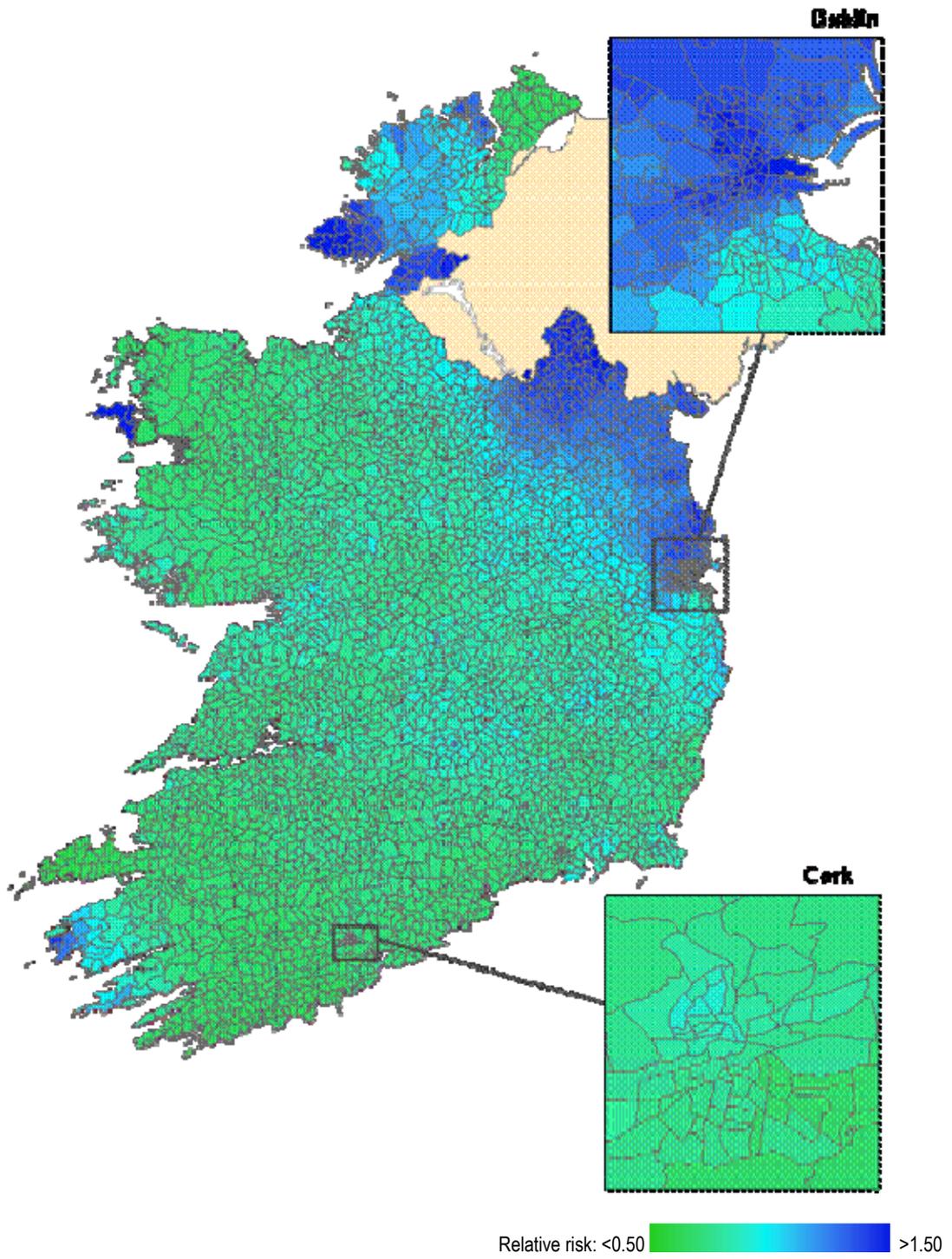
10.5 Mapping and geographical variation

Geographical variation

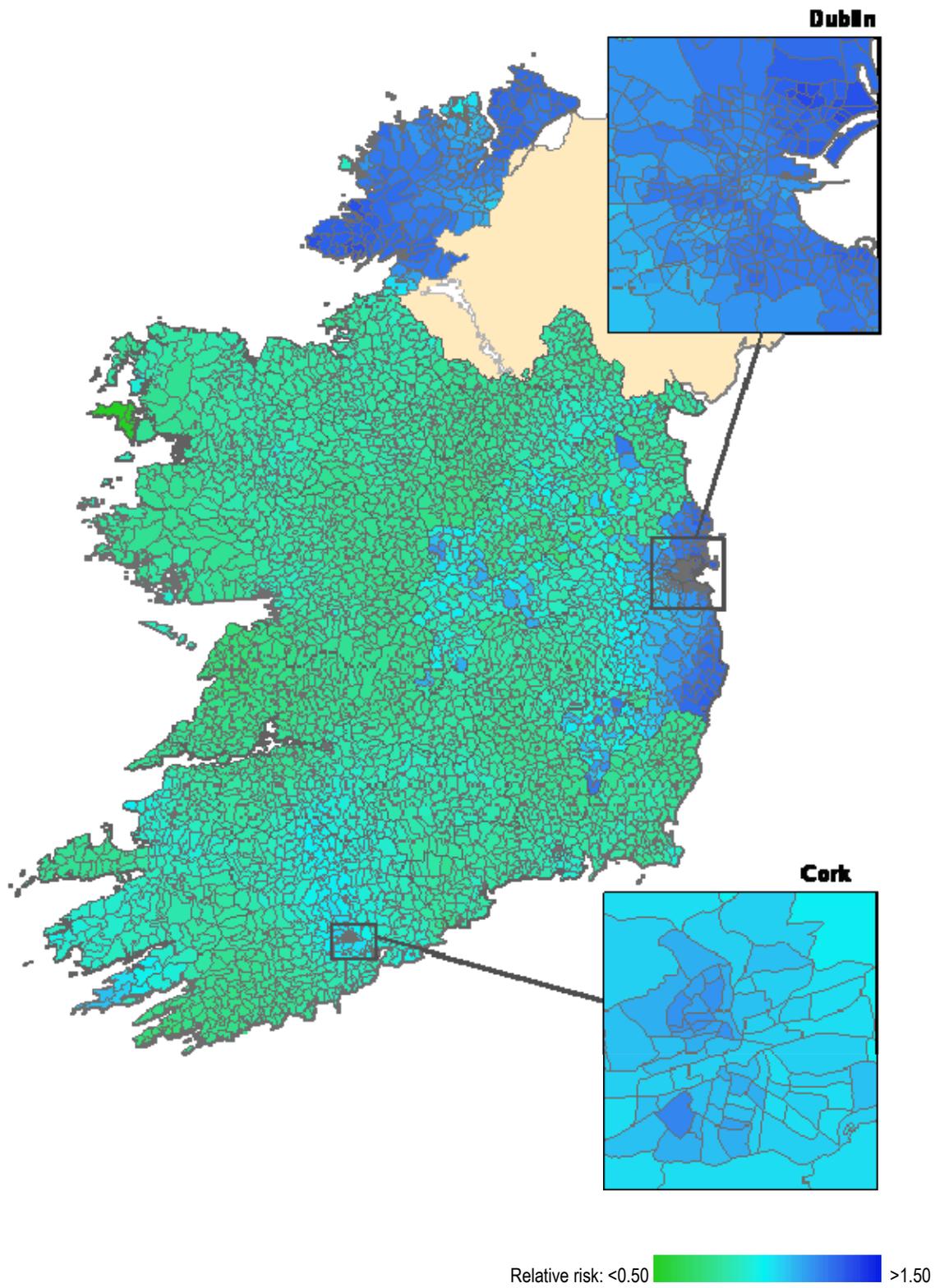
The geographical pattern of bladder cancer for both sexes combined was mostly determined by the much higher incidence in men (maps 10.1-10.3). There was more marked geographical variation for men than for women, with two notable areas of high incidence - along the east coast in Dublin and Wicklow, and in Co. Donegal. There was a less pronounced area of high incidence around Cork. Within Dublin, the north-south gradient seen for lung cancer (map 7.2) and for stomach cancer (figure 9.8) was not apparent for bladder cancer (map 10.3). For women, the pattern was somewhat different, and less distinct, but there were again areas of higher incidence around Dublin (mainly confined to the city) and in Donegal, confined mainly to the Inishowen peninsula, and a trend of slightly increasing incidence heading towards the southwest.

There were some similarities between these maps and those for lung cancer (maps 7.1-7.3), illustrating the influence of tobacco on bladder cancer risk. However, some of the areas with higher bladder cancer incidence did not have particularly high rates of lung cancer (e.g. most of Co. Donegal for men, southwest for women). In addition, there was no striking correspondence between the geographical distribution of bladder cancer and that of levels of current smoking reported in the SLÁN survey (Appendix 1). These observations suggest that other aetiological factors may play a role in bladder cancer incidence in Ireland.

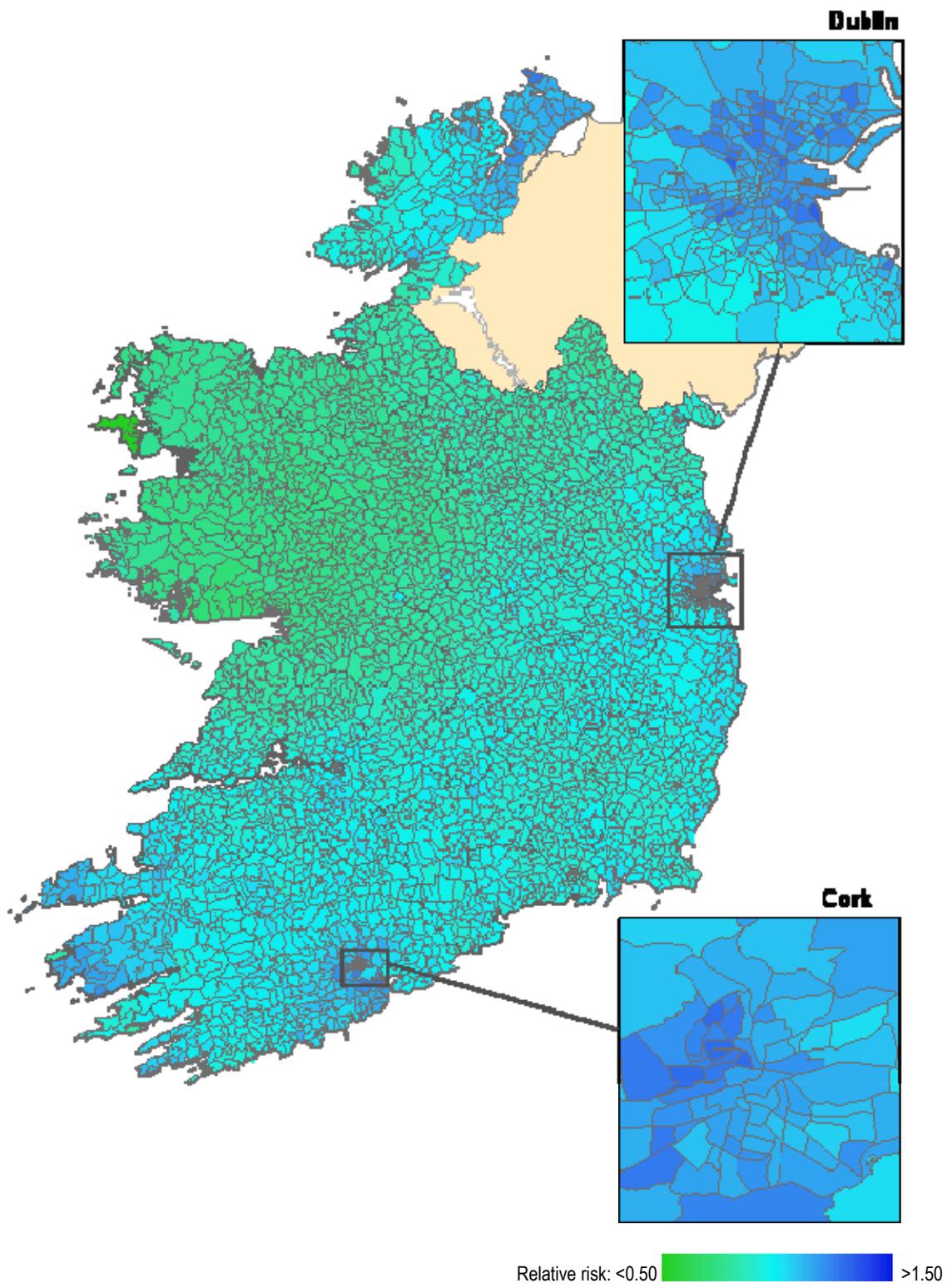
Map 10.1 Bladder cancer, smoothed relative risks: both sexes



Map 10.2 Bladder cancer, smoothed relative risks: males



Map 10.3 Bladder cancer, smoothed relative risks: females



11 Melanoma of the skin

11.1 Summary

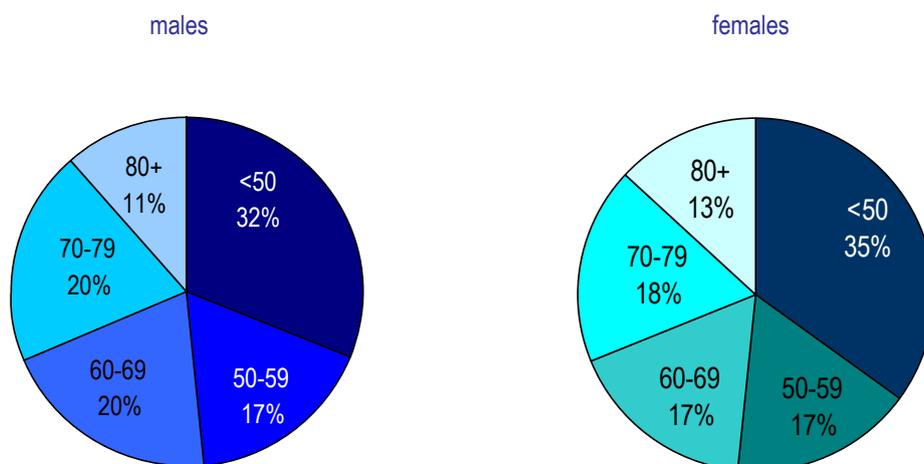
Melanoma of the skin is the ninth most common cancer in Ireland, accounting for 2.4% of all malignant neoplasia in men and 4.2% in women, if non-melanoma skin cancers are excluded (table 11.1). Each year, approximately 162 men and 266 women are diagnosed with melanoma. Incidence rates rose between 1994 and 2003, by approximately 2% annually in women and 4% in men.

Table 11.1 Summary information for melanoma skin cancer in Ireland, 1994-2003

	females	males
% of all new cancer cases	3.0%	1.7%
% of all new cancer cases excluding non-melanoma skin cancer	4.2%	2.4%
Average number of new cases per year	266	162
Average number of deaths per year	63	100
Age standardised incidence rate per 100,000 (European standard population)	14.2	9.8
Estimated annual percentage change in rate 1994-2003	2.3%	3.7%

The average age at diagnosis with melanoma is younger than for most other cancers. The age distribution is similar for men and women (figure 11.1). The majority of patients (69% of both men and women) were under 70 at the time of diagnosis while 32% of men and 35% of women were aged under 50. However, there was also a substantial proportion (13% of women and 11% of men) aged 80 and over.

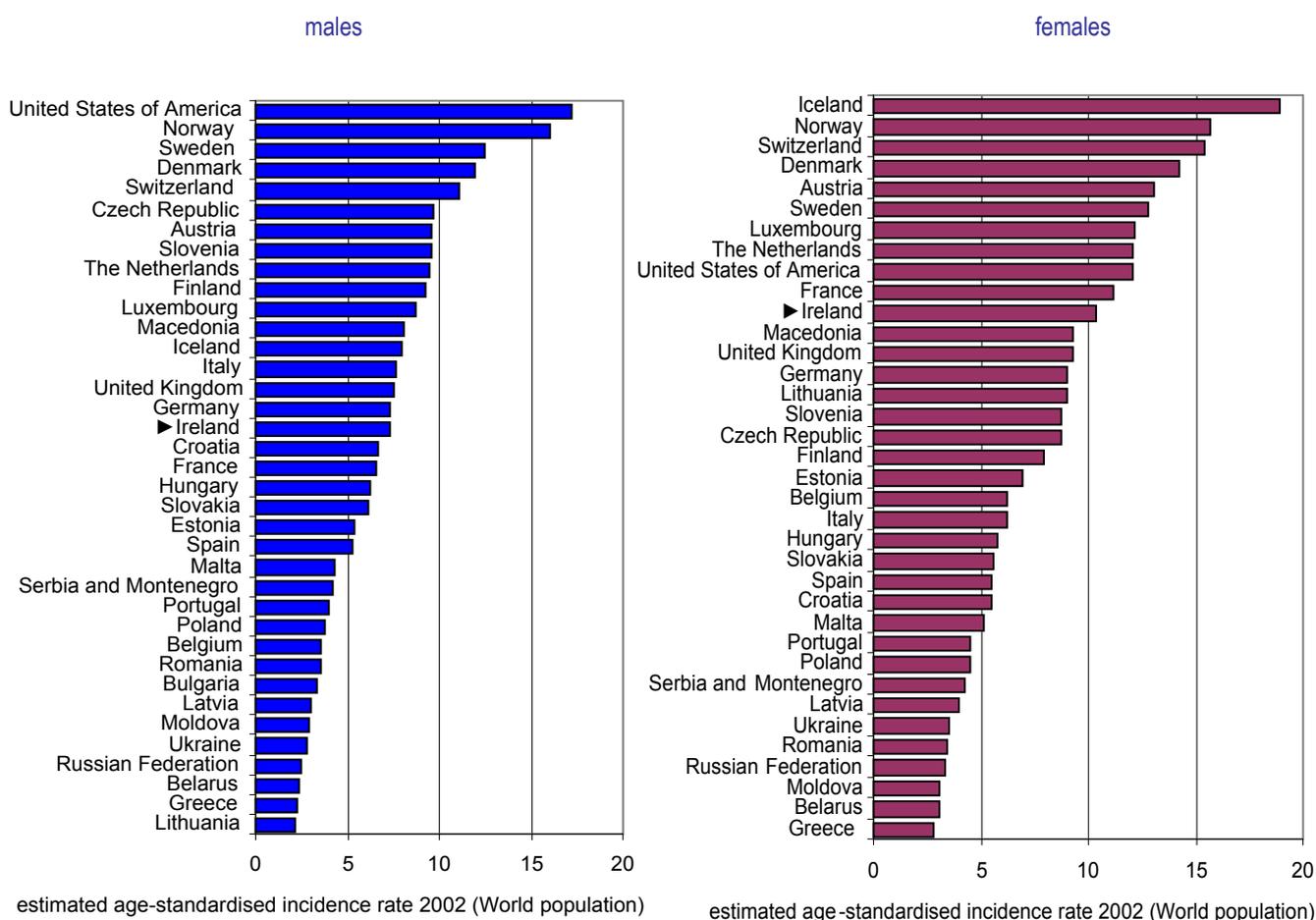
Figure 11.1 Age distribution of melanoma cases, 1994-2003, males and females



11.2 International variations in incidence

Melanoma incidence in men in Ireland is close to the mid-point of rates for Europe as a whole and is similar to that in the UK (figure 11.2). For women it is in the upper half of European rates, exceeds that for women in the UK by 40%, and is at a similar level to the rate in the USA. It is not clear why incidence in women in Ireland is higher than in the UK, but it is most likely that there are differences in exposure to risk factors for the disease between the countries.

Figure 11.2 Estimated incidence rate per 100,000 in 2002 for Europe and USA: melanoma of the skin



Source: GLOBOCAN 2002 (Ferlay et al, 2004)

11.3 Risk factors

Table 11.2 Risk factors for melanoma of the skin, by strength of evidence

	Increases risk	Decreases risk
<i>Convincing or probable</i>	Sun exposure (mainly recreational) ¹⁻³	
	Sunbed/sunlamp use ⁴	
	History of sunburn ¹⁻³	
	Presence of benign sun damage in the skin ²	
	Number of naevi ^{2,5,6}	
	Density of freckles or freckling as a child ^{2,7}	
	Skin, hair and eye colour ^{1,2,7}	
	Ability to tan ²	
	Family history of melanoma ^{7,8}	
	High socio-economic status ⁹	
<i>Possible</i>		Oral contraceptives ¹⁰

¹ International Agency for Research on Cancer, 2001; ² Armstrong and Kricger, 2001; ³ Gandini et al, 2005b; ⁴ Gallagher et al, 2005; ⁵ risk raised for high numbers of either common or atypical naevi or both; ⁶ Gandini et al, 2005a; ⁷ Gandini et al, 2005c; ⁸ melanoma in one or more first degree relatives; ⁹ Faggiano et al, 1997; ¹⁰ Karagas et al, 2002

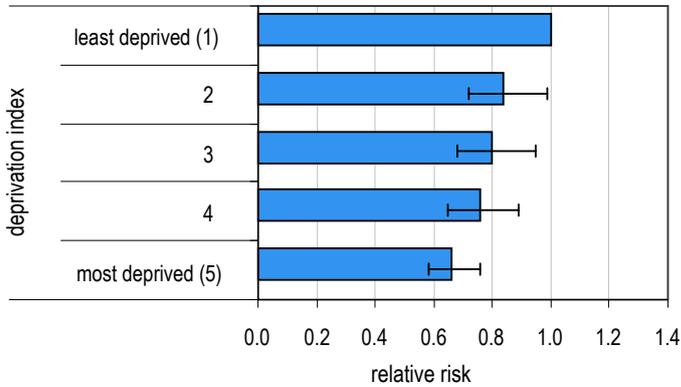
The main cause of melanoma of the skin is exposure to ultraviolet (UV) radiation, the primary source of which is sunlight. Intermittent, or recreational, sun exposure is the most important risk factor (table 11.2). A history of sunburn, often considered to be a marker of high levels of intermittent sun exposure, is associated with raised risk, as is presence of benign sun damage (solar keratoses) in the skin. Recent evidence confirms that exposure to artificial UV radiation, through use of sunbeds or sunlamps, also increases risk. Constitutional factors act together with UV exposure to influence the chance of an individual developing melanoma. Risk is increased in those with more naevi (moles), a high density of freckles (or who had freckling as a child), light hair, skin or eye colour, and reduced ability to tan.

Melanoma risk is higher in those of higher socio-economic status and it has been suggested that this may be due to greater recreational sun exposure among more affluent groups.

Individuals with first degree relatives who have had melanoma have an increased risk of developing it themselves. The genetic basis for this risk is currently being explored in genome-wide association studies; these are endeavouring to identify the genetic variants associated with melanoma *per se*, and with eye, hair and skin colour and ability to tan (Easton and Eeles, 2008).

11.4 Electoral district characteristics and cancer incidence

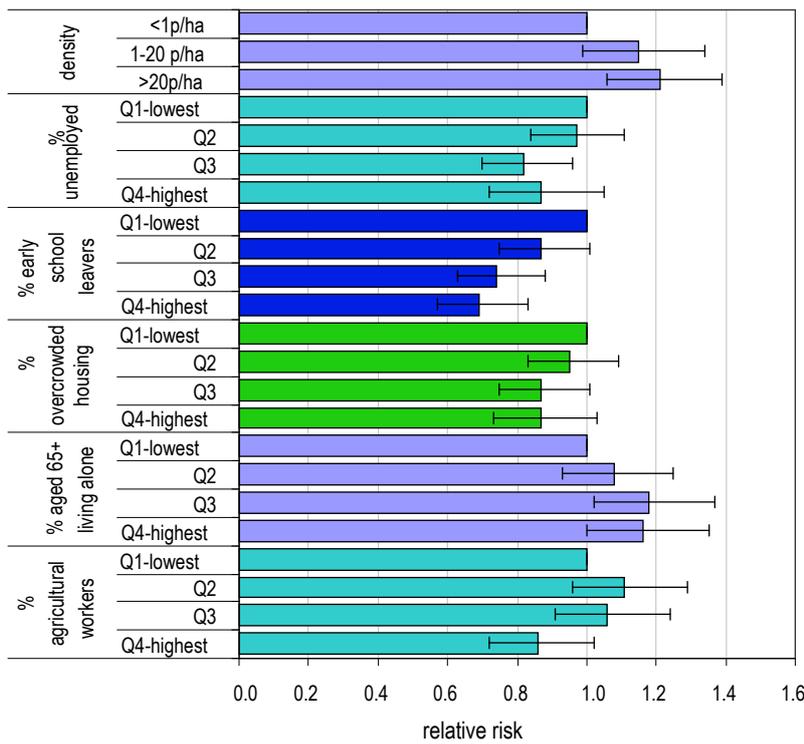
Figure 11.3 Adjusted relative risks of melanoma of the skin by deprivation index: males



Adjusted for population density

There was a strong trend of decreasing risk of melanoma in men with increasing deprivation (figure 11.3). Incidence in the most deprived areas was one-third lower than incidence in the least deprived areas (RR=0.66, 95% CI 0.58-0.76).

Figure 11.4 Adjusted relative risks of melanoma of the skin by area characteristics: males



All variables mutually adjusted except % of agricultural workers (not adjusted for density)

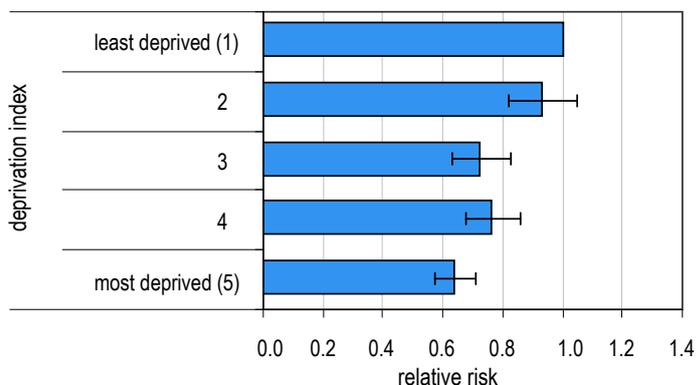
The incidence of melanoma in men was significantly higher in urban areas (>20p/ha) than in rural areas (<1p/ha) (figure 11.4; RR=1.21, 95% CI 1.06-1.39).

Areas with a higher proportion of agricultural workers had a slightly lower incidence, but this was not statistically significant.

Areas with a higher proportion of early school leavers were associated with a significantly lower risk. Areas with a higher rate of unemployment and of overcrowded housing were also associated with lower risk, however these associations were weak.

The risk of melanoma was higher in areas with a higher proportion of people aged 65 and over living alone.

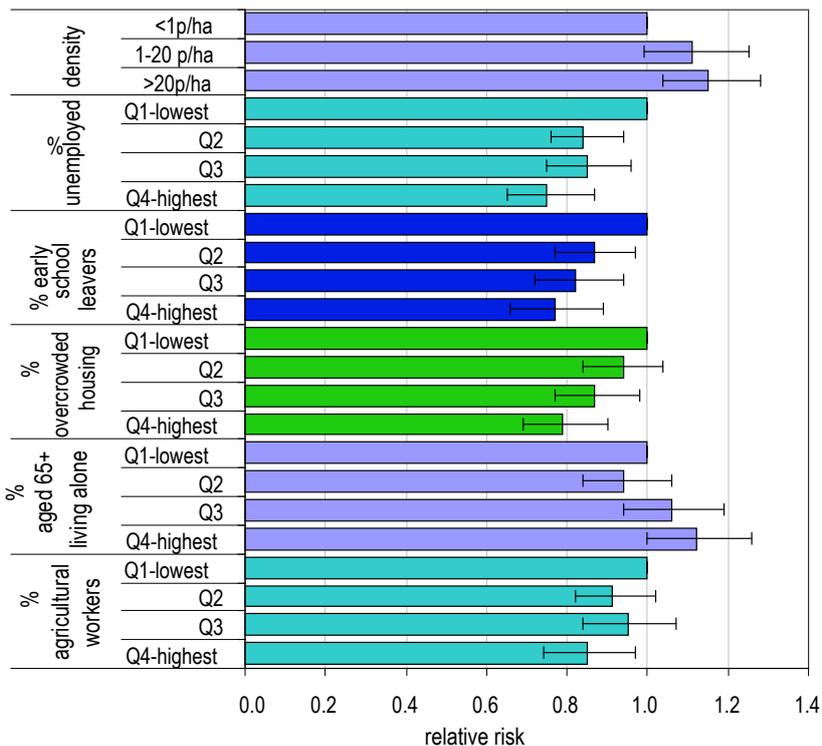
Figure 11.5 Adjusted relative risks of melanoma of the skin by deprivation index: females



As for men, melanoma risk tended to fall with increasing deprivation, and the most deprived areas had an incidence that was one-third lower than the least deprived areas (RR=0.64, 95% CI 0.57-0.71; figure 11.5).

Adjusted for population density

Figure 11.6 Adjusted relative risks of melanoma of the skin by area characteristics: females



More densely populated areas had a higher incidence of melanoma. The relative risk in the most densely, compared to the least densely, populated areas was 1.15 (95% CI 1.04-1.28; figure 11.6).

Melanoma incidence was significantly lower in areas with high unemployment, a high proportion of early school leavers, overcrowded housing and more agricultural workers.

Risk was higher in areas with a higher proportion of persons aged 65 and over living alone.

All variables mutually adjusted except % of agricultural workers (not adjusted for density)

Socio-economic variation

Deprivation and urban/rural residence were both strongly related to melanoma incidence, but in contrast to other cancers, where these factors had similar effects, for melanoma the effects were in opposition. There was a strong relationship, for both men and women, between affluence, as measured in various ways, and higher melanoma incidence. This confirms the evidence from the literature that melanoma in Ireland is currently mainly due to recreational, rather than occupational, UV exposure. However, better surveillance and over-diagnosis of lesions

with low malignant potential, in populations with more health awareness and greater access to medical services, may also be a factor.

11.5 Mapping and geographical variation

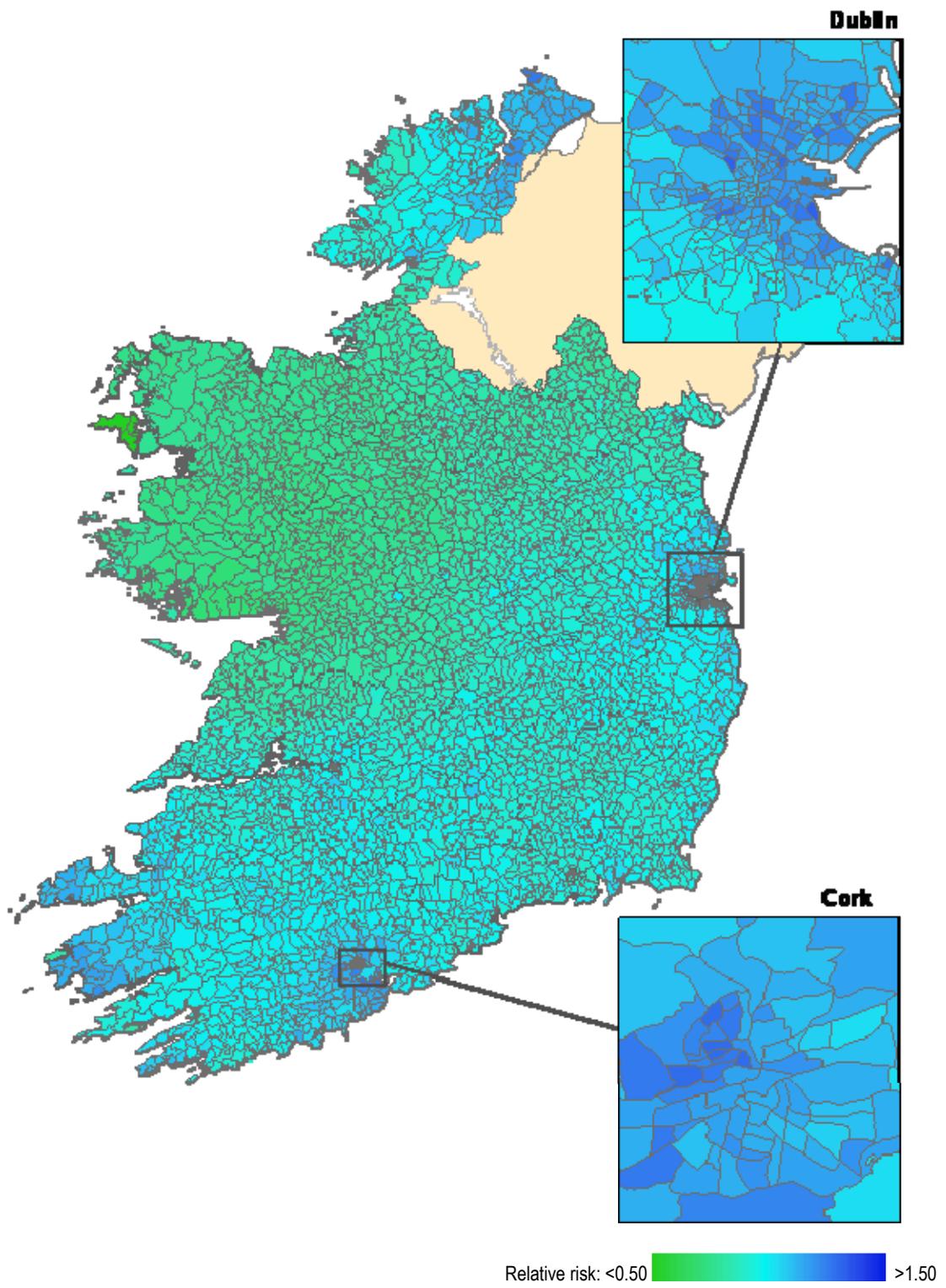
Geographical variation

The geographical distribution of melanoma was quite similar for males and females (maps 11.1-11.3) and there was some resemblance to the geographical pattern of non-melanoma skin cancer (maps 4.1-4.3).

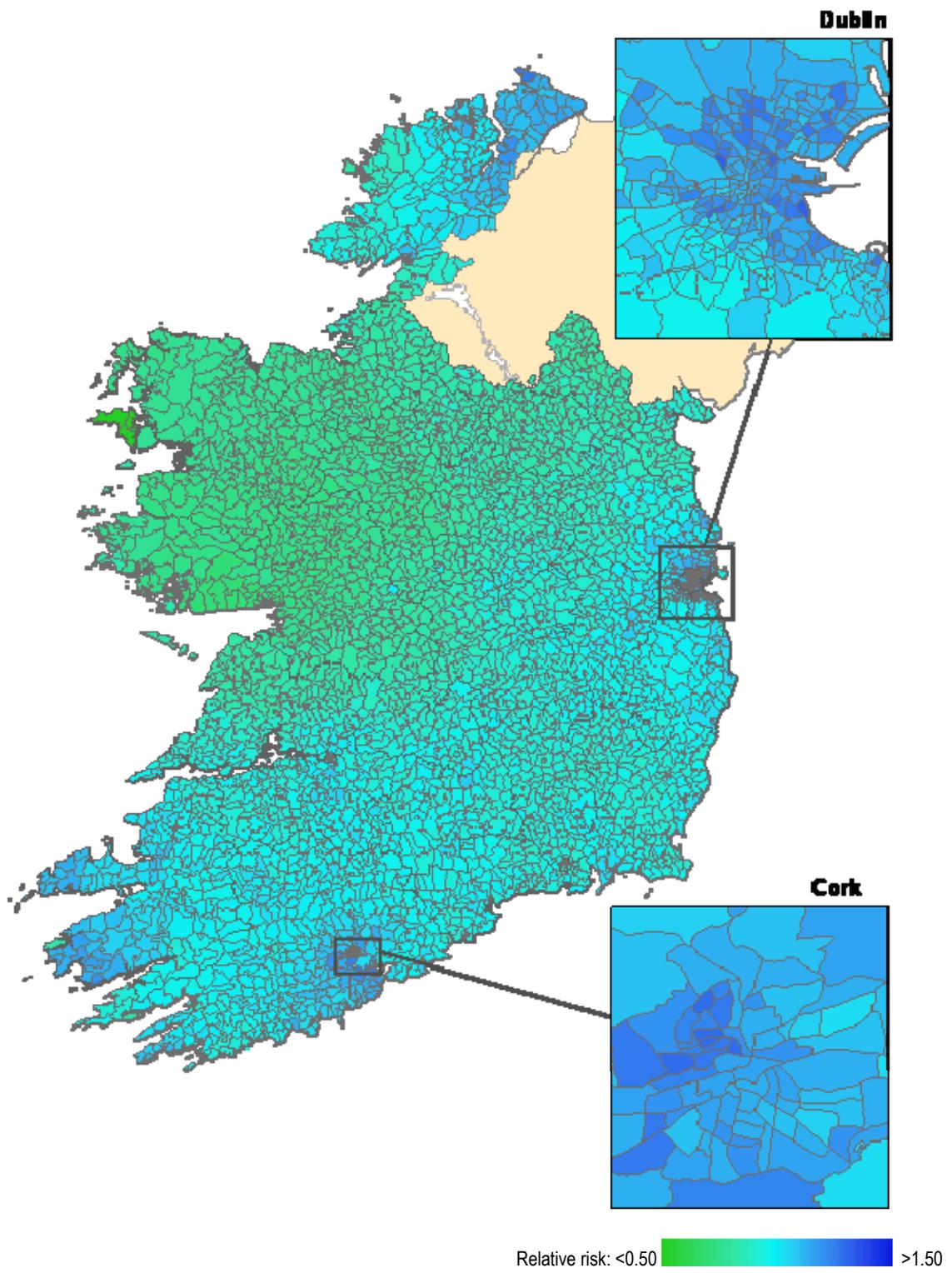
In both sexes, while there were areas of higher incidence in west Cork, to the north of Dublin and along the west coast in Donegal, incidence was highest around the major urban centres of Dublin and Cork, around Waterford and in south Wexford. Among men, there were also some patches of higher incidence in the west, on the coast of counties Galway and Mayo. For women, the area of higher incidence around Dublin was more dispersed than for men. Within Dublin itself, the highest incidence areas tended to be more concentrated in the south of the city, whereas in Cork, incidence was high in almost the entire city, particularly for men.

Some similarities to the map of household income from the SLÁN survey (Appendix 1) were apparent. In the greater Dublin area, there was some concordance between areas with higher melanoma incidence and areas of higher income; this was less obvious, although still present, in Cork.

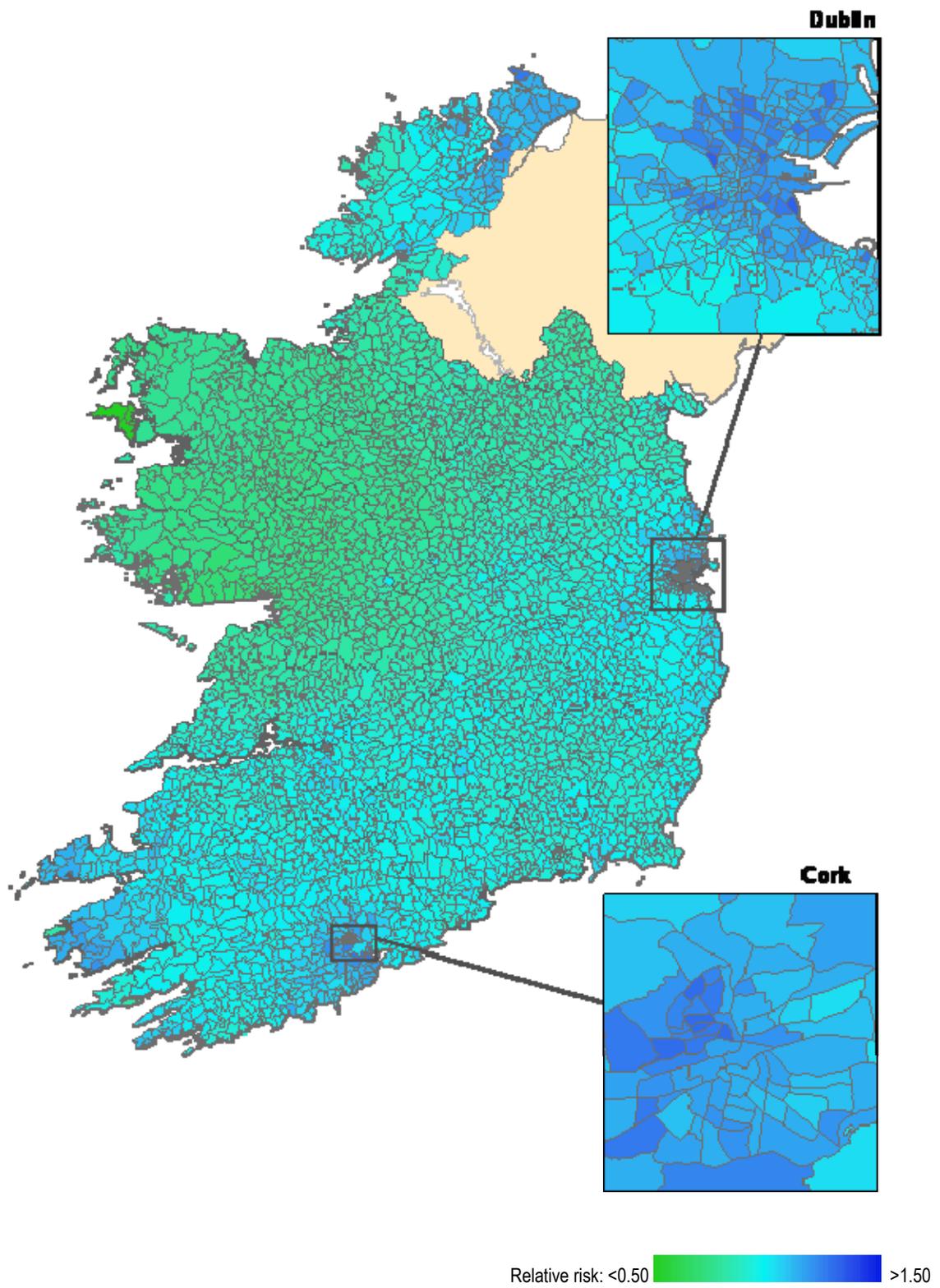
Map 11.1 Melanoma of skin, smoothed relative risks: both sexes



Map 11.2 Melanoma of skin, smoothed relative risks: males



Map 11.3 Melanoma of skin, smoothed relative risks: females



12 Head and neck cancer

12.1 Summary

Head and neck cancers are the 11th most common cancer in Ireland, accounting for 2.8% of all cancers in men and 1.1% in women, when non-melanoma skin cancer is excluded (table 12.1). Each year, approximately 276 men and 101 women are diagnosed with a tumour in the head and neck. During 1994-2003, incidence decreased by 2.5% per annum in men and rose by slightly over 1% per annum in women.

Table 12.1 Summary information for head and neck cancer in Ireland, 1994-2003

	females	males
% of all new cancer cases	0.8%	2.0%
% of all new cancer cases excluding non-melanoma skin cancer	1.1%	2.8%
Average number of new cases per year	101	276
Average number of deaths per year (ICD9 140-148)	96	37
Age standardised incidence rate per 100,000 (European standard population)	5.3	17.4
Estimated annual percentage change in rate 1994-2003	1.2%	-2.5%

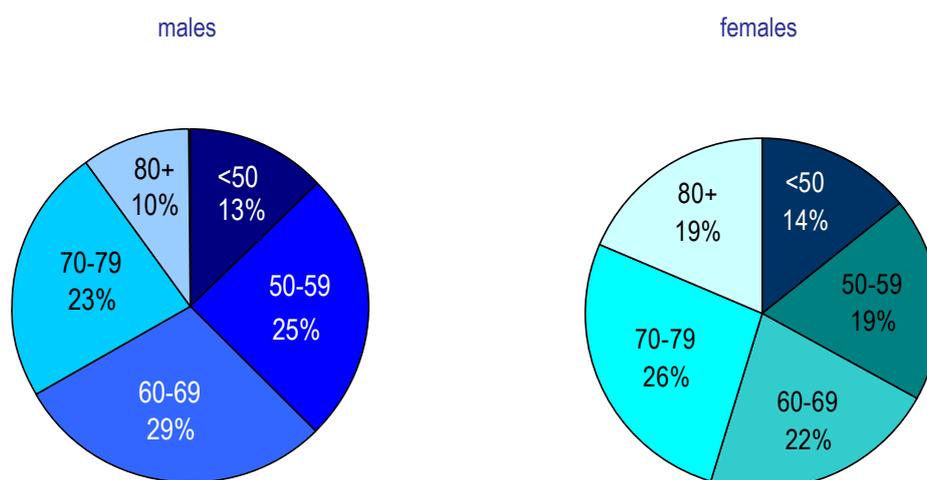
Head and neck cancer is a collective term for a range of cancers encompassing more than 15 major sites and over 30 specific sub-sites (table 12.2). In both sexes, the largest number are cancers of the larynx (35% in men and 20% in women), and cancers of the tongue (15% in men and 16% in women). Lip cancers have been excluded from the analysis, as cancers of the skin of lip (usually grouped with skin cancers) and cancers of the lip (grouped with head and neck cancers) are often difficult to distinguish in practice, making data on cancer of the lip relatively unreliable. Cancers of the lip also have more in common, aetiologically, with non-melanoma skin cancer than with other cancers of head and neck.

The age distribution of head and neck cancer was different for males and females (figure 12.1). Two-thirds of cases in men, but just over half in women, were aged under 70 at diagnosis, while the proportion of women diagnosed at 80 or over was nearly twice that of men (19% vs 10%). However, because of the much higher number of men with these cancers, the absolute number of men affected was higher than that of women at every age.

Table 12.2 Sites of head and neck cancer in Ireland, 1994-2003

	ICD10 code	% of all head and neck cancers	
		females	males
base of tongue	C01	4%	5%
other tongue	C02	13%	10%
gum	C03	3%	2%
floor of mouth	C04	6%	6%
palate	C05	4%	2%
other and unspecified parts of mouth	C06	7%	4%
parotid gland	C07	8%	5%
other and unspecified major salivary glands	C08	4%	1%
tonsil	C09	5%	5%
oropharynx	C10	2%	3%
nasopharynx	C11	3%	4%
piriform sinus	C12	5%	6%
hypopharynx	C13	5%	2%
other and ill-defined sites in the oral cavity and pharynx	C14	3%	4%
nasal cavity and middle ear	C30	4%	2%
accessory sinuses	C31	5%	2%
larynx	C32	20%	36%

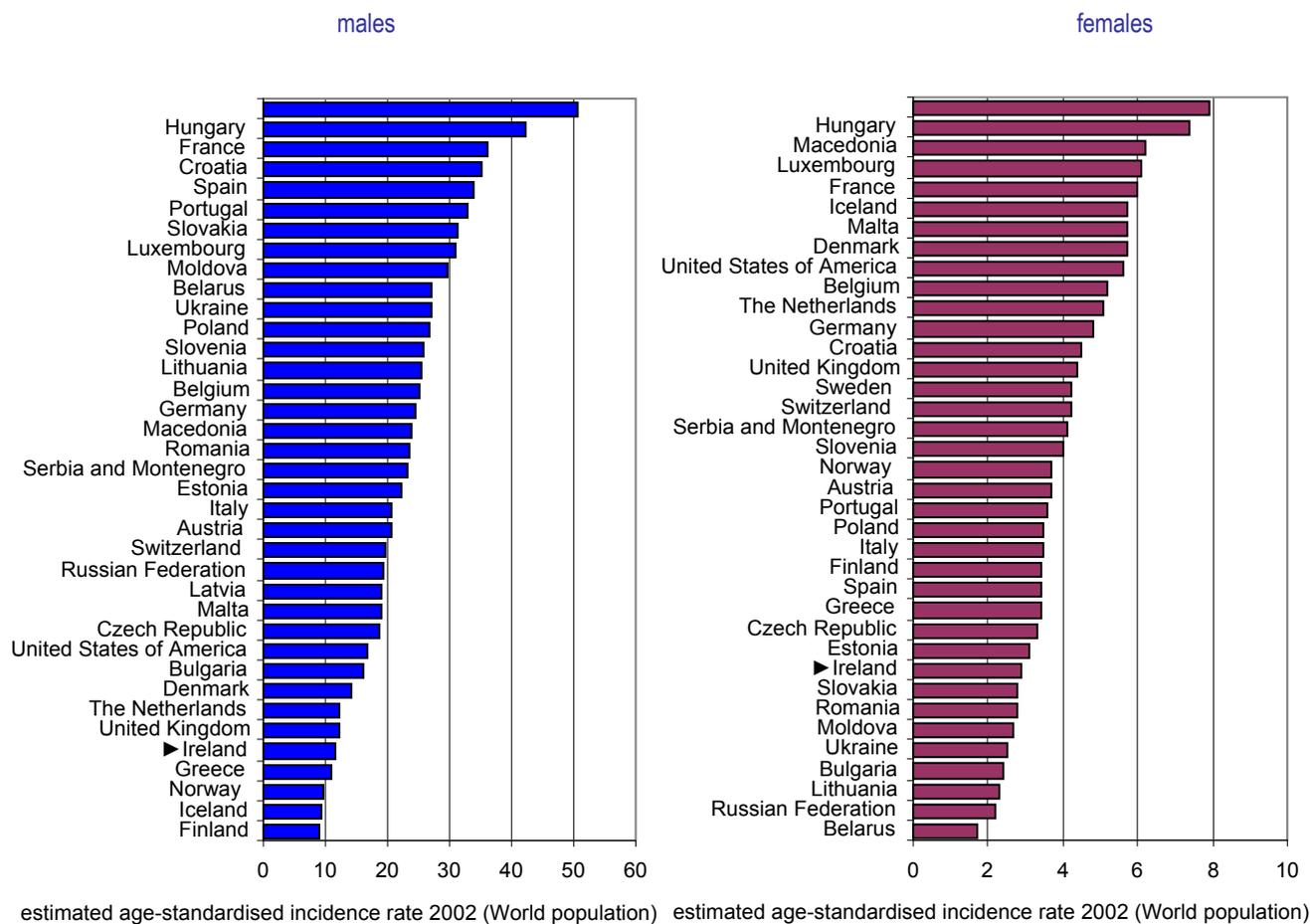
Figure 12.1 Age distribution of head and neck cancer cases, 1994-2003, males and females



12.2 International variations in incidence

Head and neck cancer incidence in both men and women in Ireland is among the lowest in Europe (figure 12.2). The incidence in men in Ireland is close to that in the UK, while that in women is much lower. International patterns in head and neck cancer are hard to interpret, because the individual cancer sites included within this group occur at different relative frequencies in different countries.

Figure 12.2 Estimated incidence rate per 100,000 in 2002 for Europe and USA: head and neck cancer



Source: GLOBOCAN 2002 (Ferlay et al, 2004)

12.3 Risk factors

Table 12.2 Risk factors for head and neck cancer, by strength of evidence

	Increases risk	Decreases risk
<i>Convincing or probable</i>	Tobacco smoking and smokeless tobacco use ^{1,2}	
	Alcohol ^{3,4}	
	Infection with human papilloma viruses (HPV) ⁵	
	Low socio-economic status ⁶	
<i>Possible</i>		Fruit ^{3,7}
		Non-starchy vegetables ^{3,7}
		Foods containing carotenoids ^{3,7,8}

¹ International Agency for Research on Cancer, 2004b; ² International Agency for Research on Cancer, 2007c; ³ World Cancer Research Fund / American Institute for Cancer Research, 2007; ⁴ International Agency for Research on Cancer, in press; ⁵ International Agency for Research on Cancer, 2007a; ⁶ Faggiano et al, 1997; ⁷ International Agency for Research on Cancer, 2003; ⁸ carotenoids are found in vegetables, particularly those which are red or orange

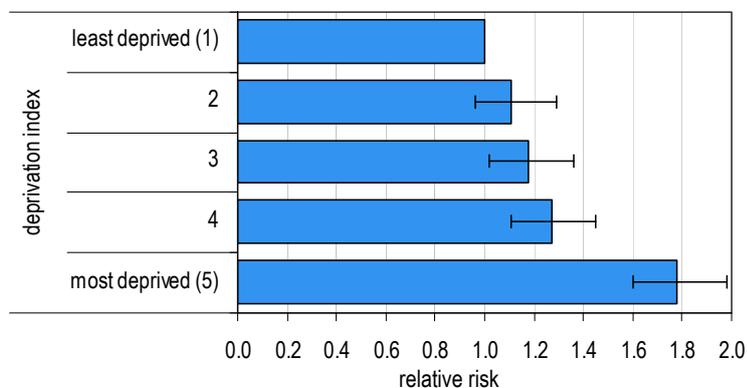
The major risk factors for most of the cancer sites within the group of head and neck cancer are the same - exposure to tobacco and alcohol (table 12.2). Both tobacco smoking and use of smokeless tobacco products, such as chewing tobacco or snuff, are causally related to many head and neck cancers. Risk increases substantially with duration of smoking and with number of cigarettes smoked, and falls with increasing time since quitting. With regard to alcohol, a causal relationship is clearly established and exposure to alcohol and smoking in combination greatly increases risk (Hashibe et al, 2009). It has been estimated that more than 70% of head and neck cancers are due to tobacco and alcohol, with 4% due to alcohol alone, 33% due to tobacco alone, and 35% due to tobacco and alcohol combined (Hashibe et al, 2009). Risk of most head and neck cancers is higher in those of lower socio-economic status, probably reflecting social class variations in exposure to tobacco and, perhaps also, alcohol.

Evidence of infection with human papilloma viruses (HPV) has been found in the oral cavity and larynx. These observations, together with results of epidemiological studies which have shown increased disease risk associated with HPV infection, has lead the International Agency for Research on Cancer to conclude that various strains of HPV are causally implicated in some head and neck cancers (International Agency for Research on Cancer, 2007a). However, the natural history of oral HPV infection is still unclear.

There are some suggestions from systematic reviews that higher levels of intake of fruit and vegetables (non-starchy or carotenoid-rich) are associated with decreased risk of head and neck cancer.

12.4 Electoral district characteristics and cancer incidence

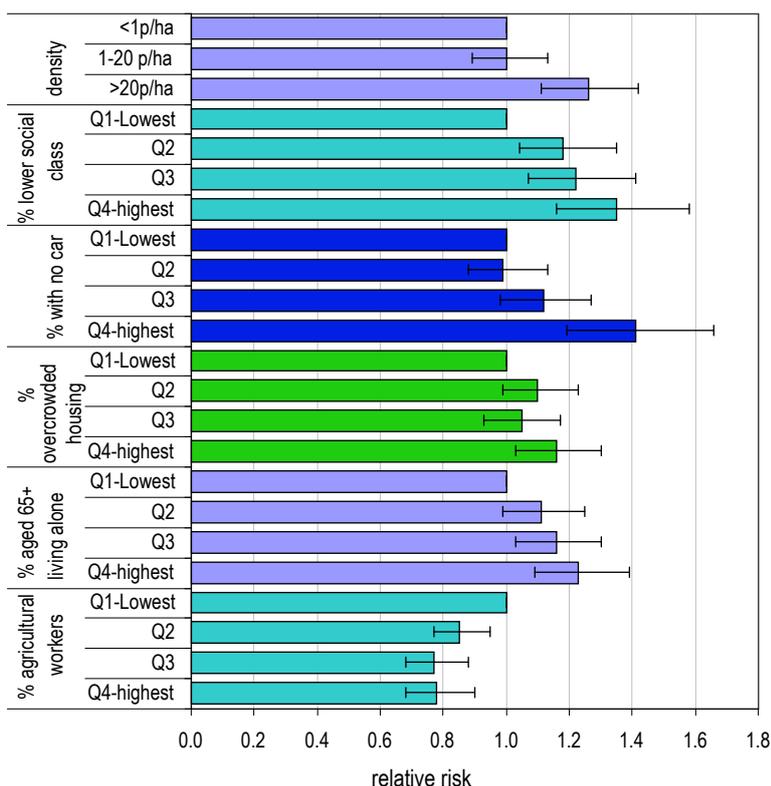
Figure 12.3 Adjusted relative risks of head and neck cancer by deprivation index: males



There was a very strong association between head and neck cancer and the deprivation index of the area of residence in men (figure 12.3). The risk of being diagnosed with a head and neck tumour was almost 80% higher in the most deprived areas compared to the least deprived (RR=1.78, 95% CI 1.60-1.98).

Adjusted for population density

Figure 12.4 Adjusted relative risks of head and neck cancer by area characteristics: males

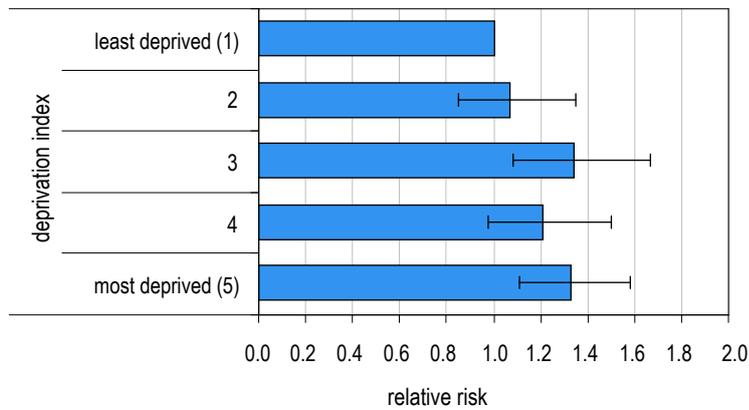


While the incidence of head and neck cancer in men was the same in areas with 1-20 p/ha as in those with <1p/ha, the most densely populated areas (>20p/ha) had a higher incidence (RR highest vs lowest=1.26, 95% CI 1.11-1.42; figure 12.2).

Incidence was higher in areas with a higher proportion of lower social class, low car ownership, overcrowded housing or of elderly persons living alone. In contrast, areas with a high proportion of agricultural workers had lower risk.

All variables mutually adjusted except % of agricultural workers (not adjusted for density)

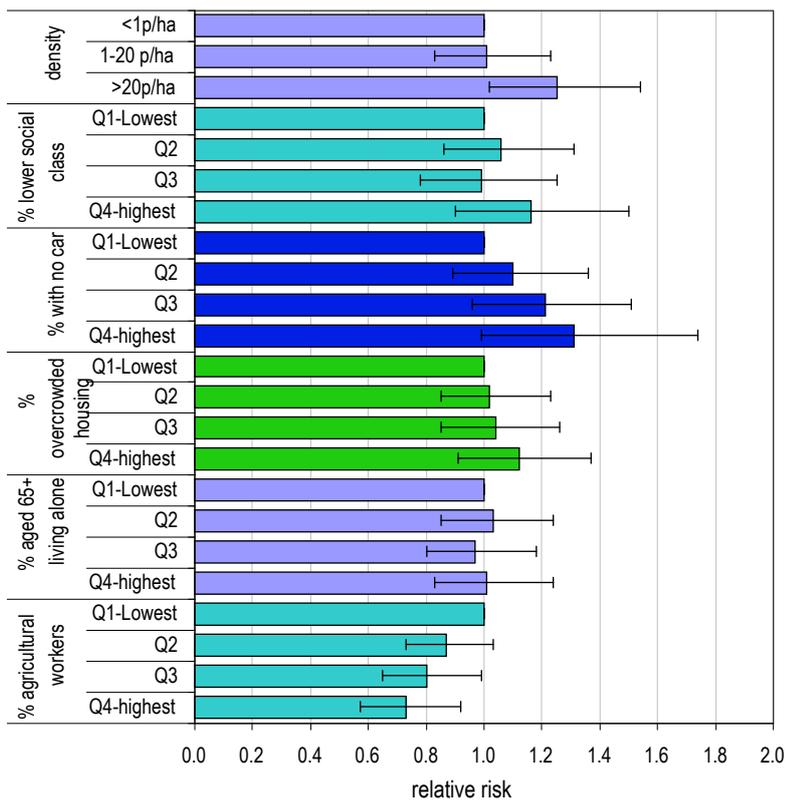
Figure 12.5 Adjusted relative risks of head and neck cancer by deprivation index: females



As with men, there was a positive relationship between deprivation and head and neck cancer in women (figures 12.5), but the association was less strong than for men (RR most vs. least deprived areas=1.33, 95% CI 1.11-1.58).

Adjusted for population density

Figure 12.6 Adjusted relative risks of head and neck cancer by area characteristics: females



Risk of head and neck cancer in women was more than 20% higher in the most densely, populated areas (RR=1.25, 95% CI 1.02-1.54; figure 12.6).

The associations of other socio-demographic variables with head and neck cancer incidence were much weaker for women than for men. While a low proportion of agricultural workers was associated with higher incidence, the associations with the proportions having no car, lower social class and overcrowded housing were not statistically significant.

All variables mutually adjusted except % of agricultural workers (not adjusted for density)

Socio-economic variation

Despite the strong association between a number of measures of deprivation and head and neck cancer in men, the association was less striking for women. This may be a result of the much higher proportion of laryngeal cancers, which are strongly tobacco-related, in men.

12.5 Mapping and geographical variation

Geographical variation

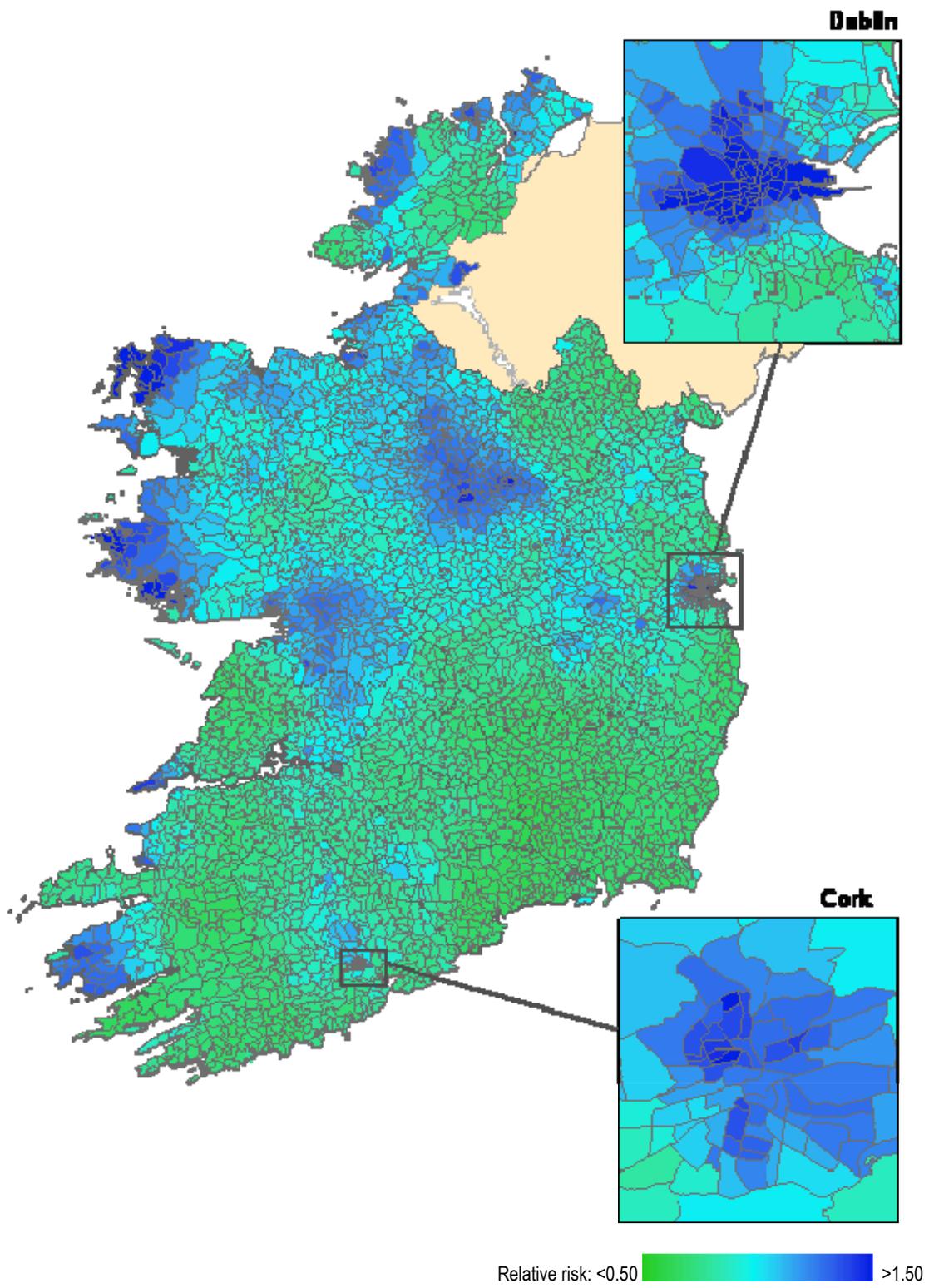
When both sexes were considered, the areas of higher incidence of head and neck cancer were, apart from the cities of Dublin and Cork, confined to the west of the country (map 12.1). When men and women were examined separately, the maps were slightly different (maps 12.2 and 12.3). For men, a number of areas appeared to have a higher incidence - Dublin, Cork, Limerick and Galway cities, a band running from Cork to Galway, a broad area in the north midlands, northwest Mayo and the Iveragh peninsula in Kerry. Within Cork and Dublin, head and neck cancer was more common in less affluent areas.

For women, there was less geographical variation in incidence than for men. There was a region of higher incidence in and around Dublin and in the northeast, with a smaller area with higher rates in the north-east tip of Donegal. In Dublin, as with men, areas of higher deprivation had a higher incidence.

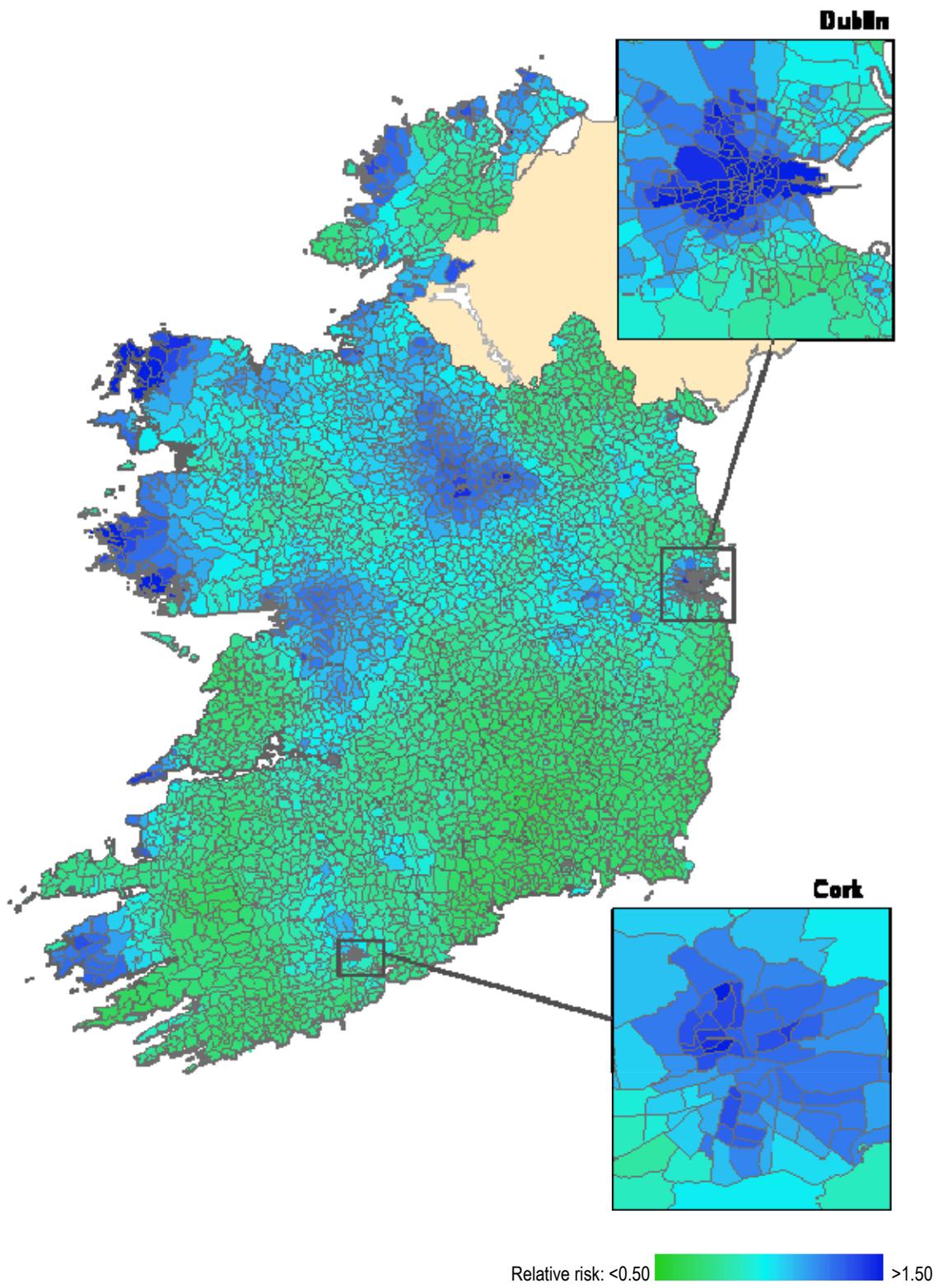
It would be interesting to know whether the areas of higher incidence in women extend into Northern Ireland. Data at the level of district councils suggests that some areas close to the border, including Fermanagh, Derry and Coleraine, have higher than average rates, (Donnelly et al, 2009).

Although the geographical distribution of head and neck cancer risk shared similarities with that for lung cancer (maps 7.1-7.3), some differences were seen, suggesting that factors other than tobacco smoking may have an influence. One possibility is alcohol, although other factors may also be involved. There were similarities between the incidence in men and the geographical pattern of heavy alcohol intake and smoking from the SLÁN survey data (Appendix 1). There were also some similarities between the pattern of head and neck cancer (for both sexes combined) and that of poverty, as measured by income, and lower social class (Appendix 1).

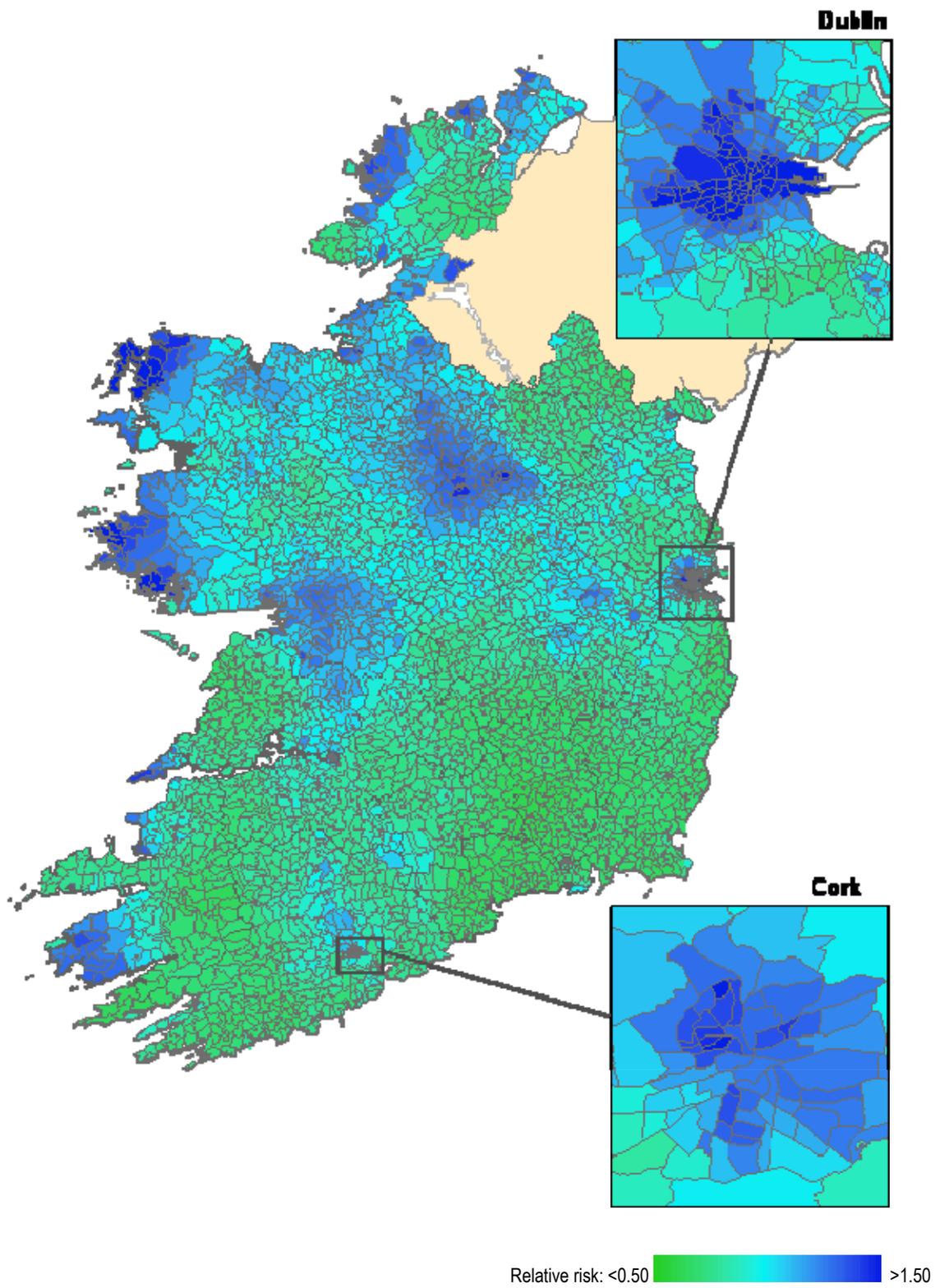
Map 12.1 Head and neck cancer, smoothed relative risks: both sexes



Map 12.2 Head and neck cancer, smoothed relative risks: males



Map 12.3 Head and neck cancer, smoothed relative risks: females



13 Oesophageal cancer

13.1 Summary

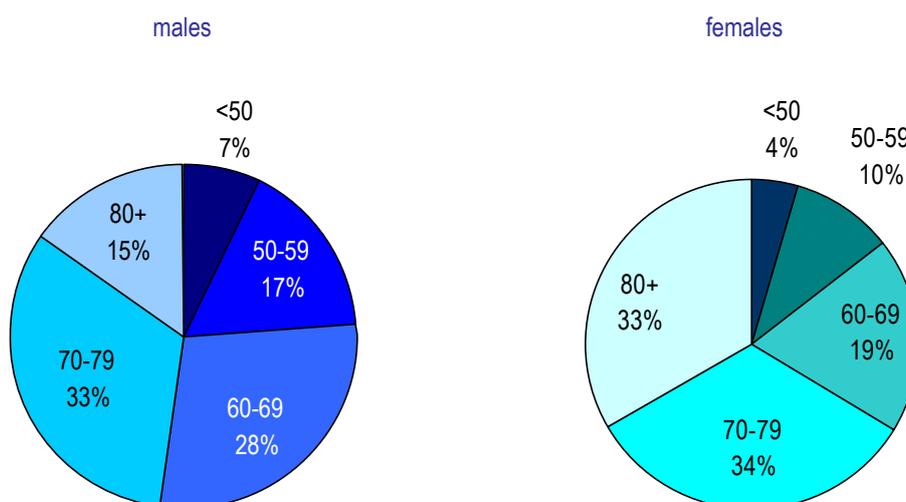
Cancer of the oesophagus ranks as the 16th most common cancer in Ireland, accounting for 2.3% of all malignant neoplasms - 2.7% in men and 1.8% in women, when non-melanoma skin cancer is excluded (table 13.1). Each year approximately 186 men and 120 women are diagnosed with a tumour in the oesophagus. During the years 1994 to 2003, incidence rates remained stable in women and decreased slightly in men.

Table 13.1 Summary information for oesophageal cancer in Ireland, 1994-2003

	females	males
% of all new cancer cases	1.3%	1.9%
% of all new cancer cases excluding non-melanoma skin cancer	1.8%	2.7%
Average number of new cases per year	120	186
Average number of deaths per year	116	192
Age standardised incidence rate per 100,000 (European standard population)	5.7	11.6
Estimated annual percentage change in rate 1994-2003	-1.4%	-0.5%

The age distribution of oesophageal cancer differs between men and women (figure 13.1). More than half of all male cases, but only one-third of female, are aged under 70 at diagnosis, while 33% of female cases are aged 80 or over.

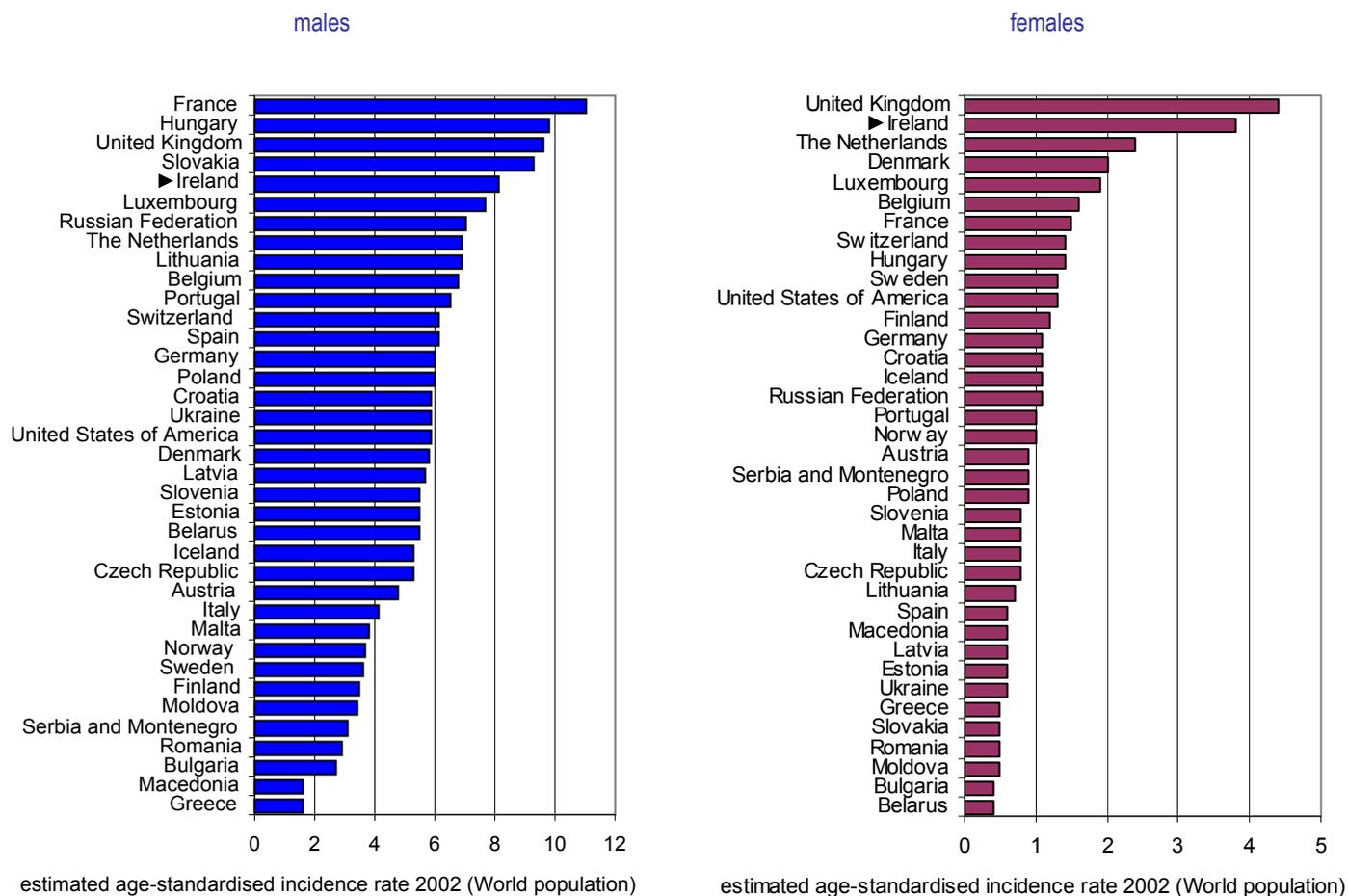
Figure 13.1 Age distribution of oesophageal cancer cases, 1994-2003, males and females



13.2 International variations in incidence

Oesophageal cancer incidence in both men and women in Ireland is among the highest in Europe (figure 13.2). The rate in Ireland is more than twice that for women in the USA and exceeds by 30% the rate in the USA in men. However, incidence rates in Ireland were lower than in the UK, which had the third highest rate in Europe in men and the highest in women.

Figure 13.2 Estimated incidence rate per 100,000 in 2002 for Europe and USA: oesophageal cancer



Source: GLOBOCAN 2002 (Ferlay et al, 2004)

13.3 Risk factors

Table 13.2 Risk factors for oesophageal cancer, by strength of evidence

	Increases risk	Decreases risk
<i>Convincing or probable</i>	Tobacco smoking and smokeless tobacco use ^{1,2}	Non-starchy vegetables ^{3,8}
	Alcohol ^{3,4}	Fruit ^{3,8}
	Body fatness/higher body mass index ³	Foods containing beta-carotene ^{3,9}
	Gastro-oesophageal reflux disease ⁵	Foods containing vitamin C ^{3,10}
	Low socio-economic status ⁶	<i>Helicobacter pylori</i> infection ^{11,12}
		Aspirin and other non-steroidal anti-inflammatory drugs ^{13,14}
<i>Possible</i>	Red meat ³	
	Processed meat ³	
	High temperature drinks ³	
	Infection with human papilloma viruses (HPV) ⁷	

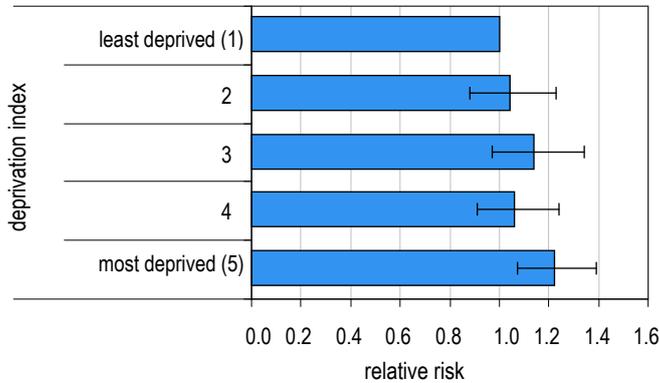
¹ International Agency for Research on Cancer, 2004b; ² Boffetta et al, 2008a; ³ World Cancer Research Fund / American Institute for Cancer Research, 2007; ⁴ International Agency for Research on Cancer, in press; ⁵ Pera et al, 2005; ⁶ Faggiano et al, 1997; ⁷ International Agency for Research on Cancer, 2007a; ⁸ International Agency for Research on Cancer, 2003; ⁹ beta-carotene is found in yellow, orange and green fruits and green leafy vegetables; ¹⁰ vitamin C is found in fruit, vegetables and tubers; ¹¹ Islami and Kamangar, 2008; ¹² Rokkas et al, 2007; ¹³ Bosetti et al, 2006; ¹⁴ Abnet et al, 2009

There are two main types of oesophageal cancer - squamous cell carcinoma and adenocarcinoma. Some risk factors are shared by both types, while others are involved in one type only. It is firmly established that tobacco smoking causes both squamous cell carcinoma and adenocarcinoma of the oesophagus. Smokers have at least a two-fold higher risk than non-smokers and risk increases with number of cigarettes smoked daily and duration of smoking. Use of smokeless tobacco products (e.g. snuff, chewing tobacco) is also associated with increased disease risk. Alcohol is also causally related to oesophageal cancer.

Obesity and overweight are positively associated with adenocarcinoma and risk increases in a dose-response fashion with increasing body mass index. In contrast, body fatness does not appear to affect risk of squamous cell carcinoma. Similarly, a past history of gastro-oesophageal reflux disease has been related to increased risk of adenocarcinoma, while infection with the *Helicobacter pylori* (*H pylori*) bacterium is associated with a reduced risk of adenocarcinoma - neither of these is associated with squamous cell carcinoma. Most, but not all, studies have found a reduced risk of adenocarcinoma in individuals who regularly use aspirin or other non-steroidal anti-inflammatory drugs. On the other hand, it is possible that HPV infection may play a role in squamous cell carcinoma, but the evidence is not entirely consistent. Various aspects of diet have been associated with oesophageal cancer risk. Higher intakes of fruit and vegetables, particularly those containing beta-carotene (yellow, orange and green fruits and green leafy vegetables) or vitamin C, probably reduce risk. Higher intakes of red or processed meat may increase risk, but the evidence is less consistent than for fruit and vegetables. Risk of oesophageal cancer is higher in those of low socio-economic status, probably reflecting variations by social class in exposure to tobacco and other lifestyle risk factors.

13.4 Electoral district characteristics and cancer incidence

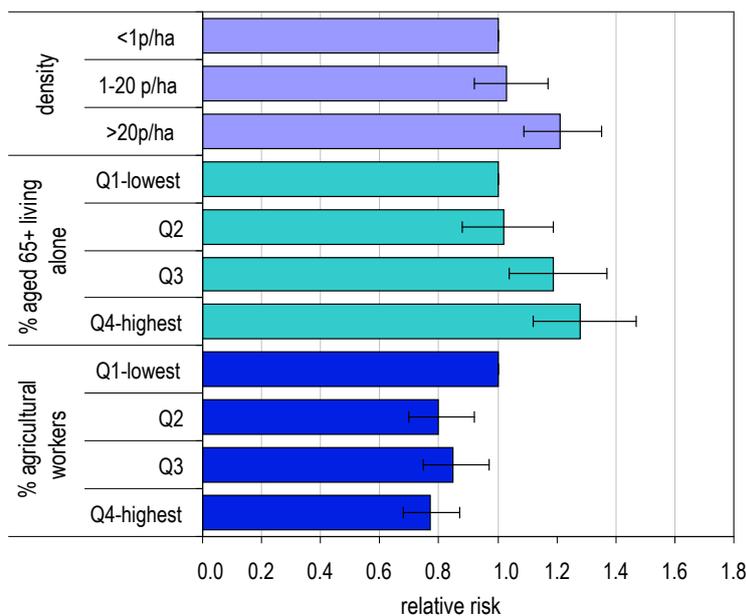
Figure 13.3 Adjusted relative risks of oesophageal cancer by deprivation index: males



Oesophageal cancer incidence in men was significantly associated with the deprivation index of their area of residence (figure 13.3). The risk in the most deprived areas was more than 20% higher than that in the least deprived areas (RR=1.22, 95% CI 1.07-1.39).

Adjusted for population density

Figure 13.4 Adjusted relative risks of oesophageal cancer by area characteristics: males



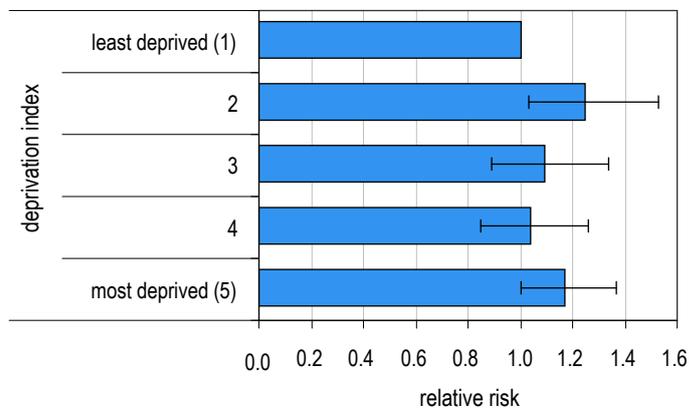
Population density was significantly associated with incidence of oesophageal cancer in men (figure 13.4). Men living in urban areas (>20 p/ha) were significantly more likely to be diagnosed with oesophageal cancer (RR=1.21, 95% CI 1.09-1.35).

In contrast, areas with the highest proportion of agricultural workers had the lowest risk of oesophageal cancer.

The only other area characteristic which was significantly associated with oesophageal cancer risk was the proportion of those aged over 65 living alone. As for other cancers, risk of oesophageal cancer in men increased with an increase in the proportion of elderly living alone.

All variables mutually adjusted except % of agricultural workers (not adjusted for density)

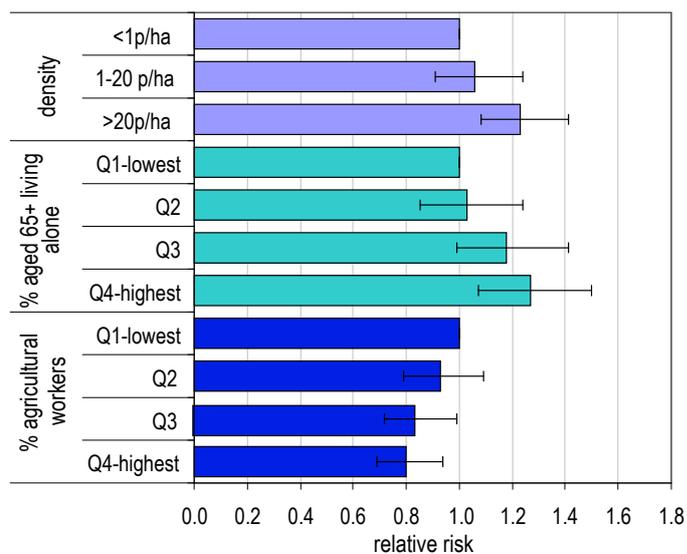
Figure 13.5 Adjusted relative risks of oesophageal cancer by deprivation index: females



As for men, the risk of oesophageal cancer in women was lowest for those residents in the least deprived areas (figure 13.5). The association in women was less strong than in men; the risk estimate for the most, compared to the least, deprived areas was 1.17 (95% CI 1.00-1.37).

Adjusted for population density

Figure 13.6 Adjusted relative risks of oesophageal cancer by area characteristics: females



Risk of oesophageal cancer in women increased with increasing population density (figure 13.6). The risk was 23% higher for women in the most, compared to the least, populated areas (RR=1.23, 95% CI 1.08-1.41).

Risk decreased with an increasing proportion of agricultural workers in the area. Other than this, as for men, the only factor significantly associated with oesophageal cancer in women was the proportion of persons aged 65 and older; areas with a higher proportion had a higher risk.

all variables mutually adjusted except % of agricultural workers (not adjusted for density)

Socio-economic variation

For both men and women, there was a significant association between both urban residence and deprivation and higher oesophageal cancer risk, although the effect of deprivation was stronger in men than women and there was not a clear trend in either sex. Apart from these, there were no significant associations between higher risk and any of the other socio-demographic variables studied. As oesophageal cancer is two separate diseases - squamous cell carcinoma and adenocarcinoma - with different risk factors, the lack of strong association with known risk factors is unsurprising. The association with the proportion of people over 65 living alone exists for almost all cancers and is difficult to explain.

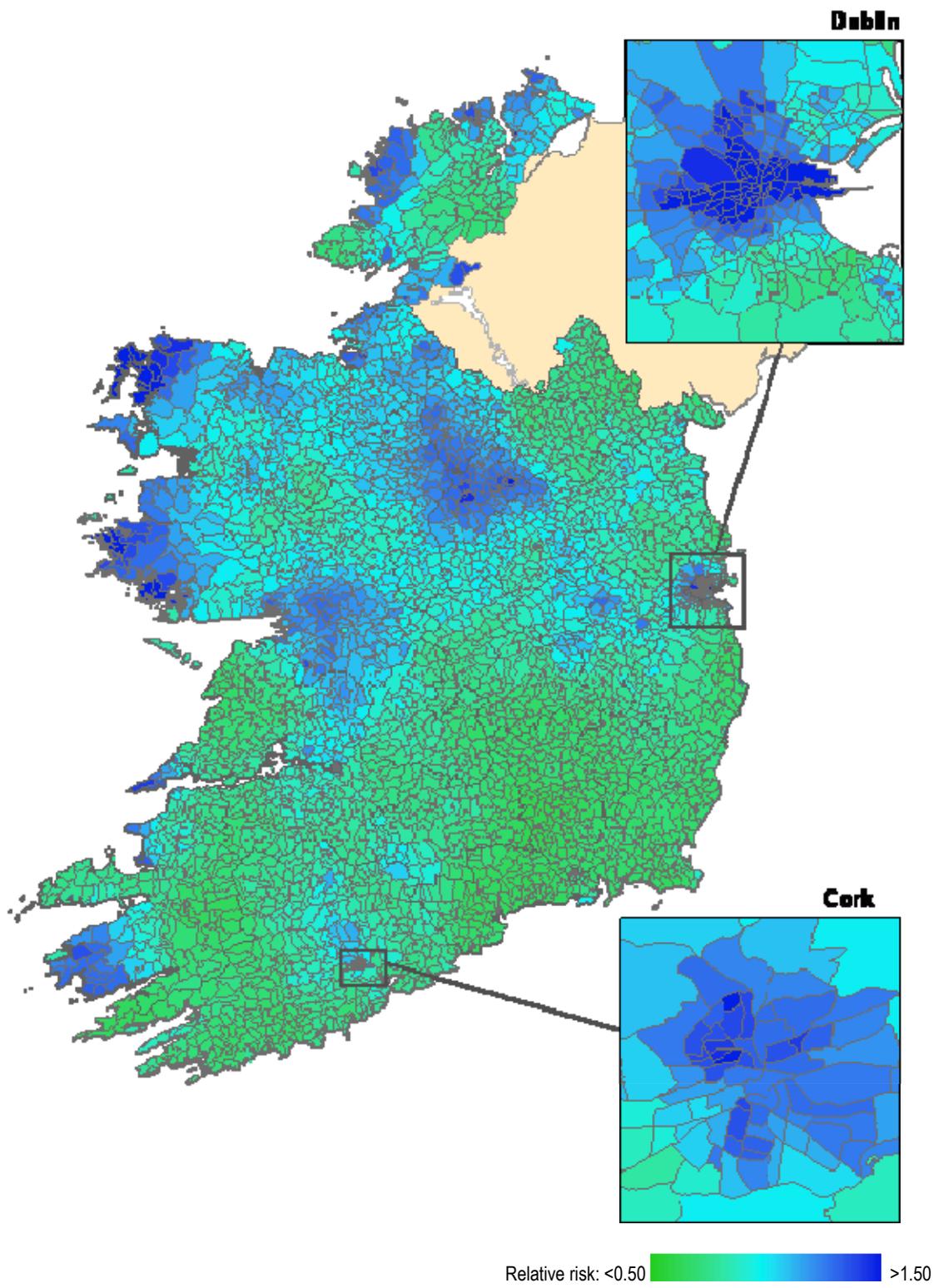
13.5 Mapping and geographical variation

Geographical variation

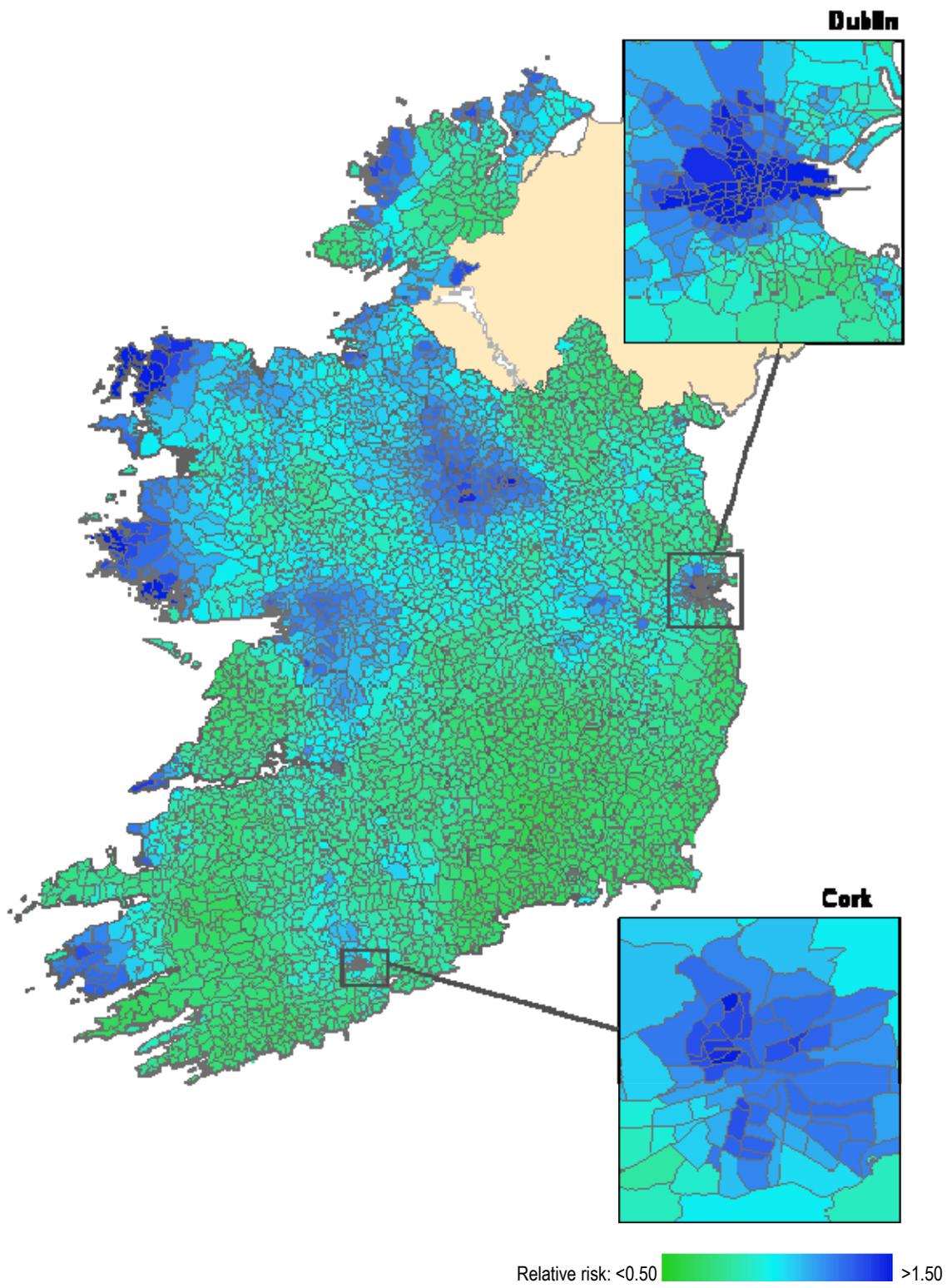
There were few areas with particularly high incidence of oesophageal cancer (maps 13.1-13.3). However, for both sexes the country was clearly split into areas of lower incidence in the northwest of the country (Galway, Clare, Sligo and Donegal counties) and those of slightly higher incidence in the northeast and running toward the south and west. Oesophageal cancer tended to be more common around Cork and Dublin cities for both men and women; for women in counties Kildare and Wicklow and for men in Louth and Monaghan.

Despite the importance of tobacco and alcohol in the aetiology of oesophageal cancer, there was no clear correspondence between the areas of higher, or lower, disease incidence and those with greater, or lesser, proportions of current smokers or heavy alcohol consumers according to the SLÁN survey (Appendix 1). Nor was there any apparent correlation with areas with a higher frequency of obesity, but this is perhaps not surprising, since the maps above relate to all oesophageal tumours and obesity is only a risk factor for adenocarcinomas. The distribution of poverty (as measured by income) from the SLÁN data was not particularly similar to that for oesophageal cancer.

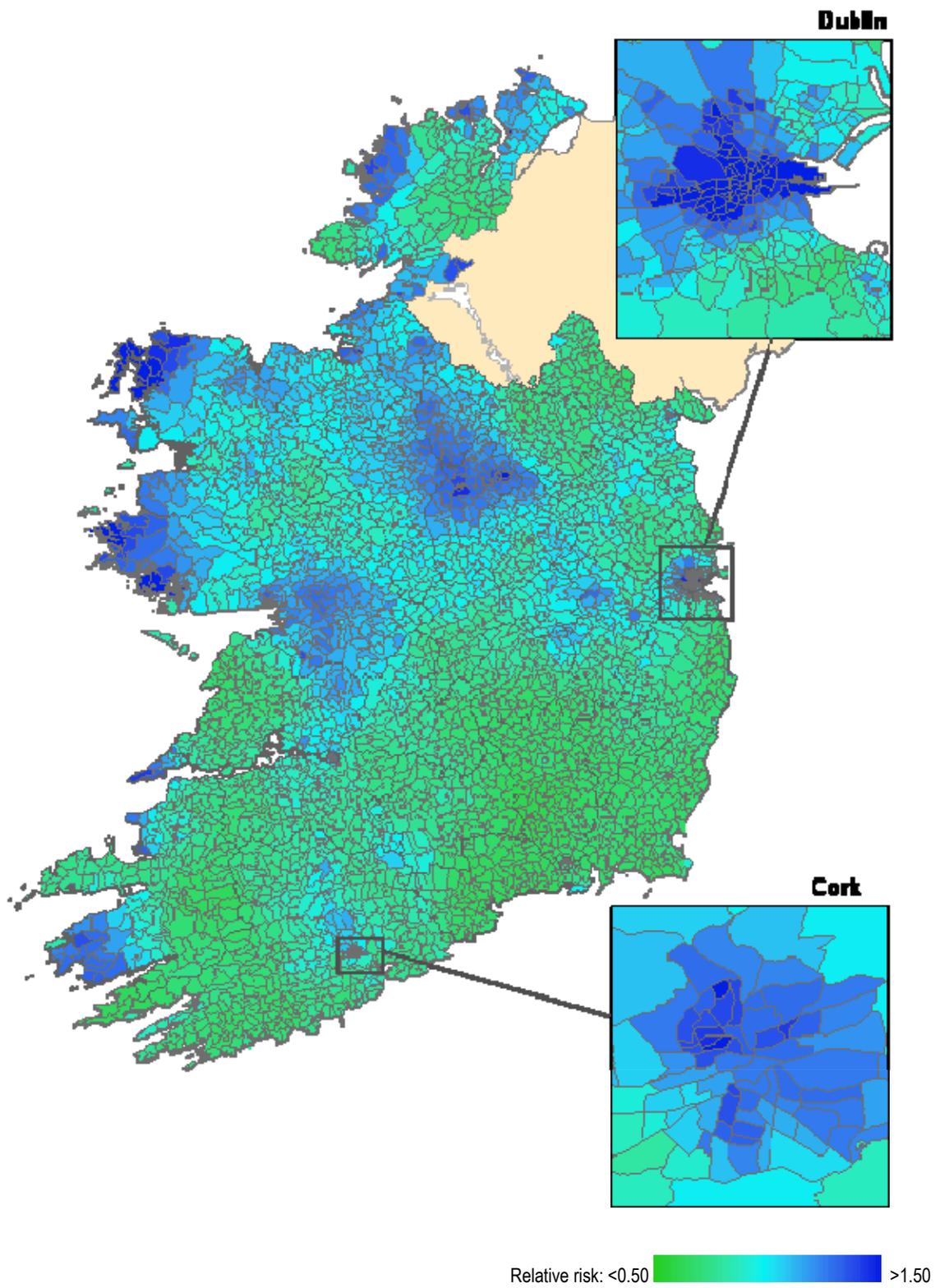
Map 13.1 Oesophageal cancer, smoothed relative risks: both sexes



Map 13.2 Oesophageal cancer, smoothed relative risks: males



Map 13.3 Oesophageal cancer, smoothed relative risks: females



14 Cervix uteri cancer

14.1 Summary

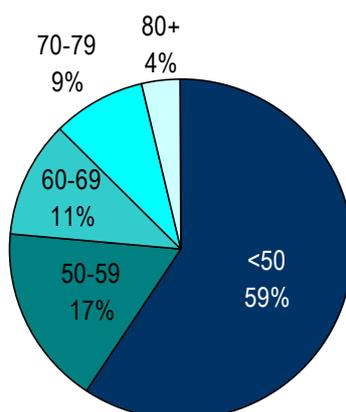
Cancer of the cervix uteri is the ninth most common cancer in women in Ireland, accounting for 2.1% of all malignant neoplasms in women, when non-melanoma skin cancers are excluded (table 14.1). Each year, approximately 183 women are diagnosed with cervical cancer. During 1994-2003, incidence rates remained stable over time.

Table 14.1 Summary information for cervical cancer in Ireland, 1994-2003

% of all new cancer cases	2.0%
% of all new cancer cases excluding non-melanoma skin cancer	2.1%
Average number of new cases per year	183
Average number of deaths per year	73
Age standardised incidence rate per 100,000 (European standard population)	10.3
Estimated annual percentage change in rate 1994-2003	-0.4%

Cancer of the uterine cervix is predominantly a disease of younger women (figure 14.1). Over half are aged under 50 at diagnosis and three-quarters under 60. Of the remainder, 11% are aged 60-69 at diagnosis, 9% aged 70-69 and 4% are 80 and older.

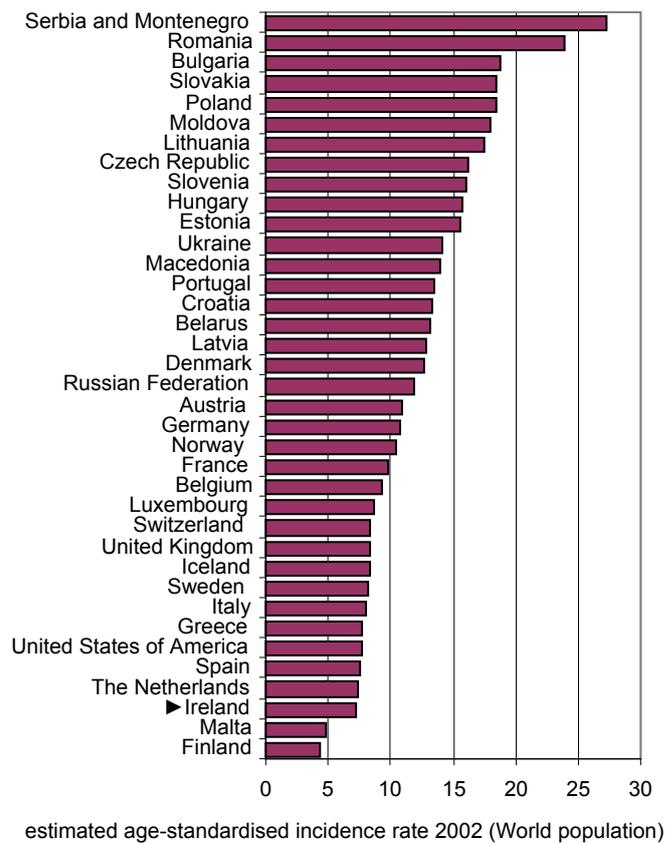
Figure 14.1 Age distribution of cervical cancer cases, 1994-2003



14.2 International variations in incidence

There is a very wide range of variation in cervical cancer incidence across Europe (figure 14.2). International variations are difficult to interpret, as they are influenced by intensity of screening as well as exposure to known risk factors; effective cervical cancer screening can reduce the incidence of the disease in the population. The estimated incidence in Ireland in 2002 was one of the lowest rates in Europe, despite the absence of a population-based screening programme at that time.

Figure 14.2 Estimated incidence rate per 100,000 in 2002 for Europe and USA: cervical cancer



Source: GLOBOCAN 2002 (Ferlay et al, 2004)

14.3 Risk factors

Table 14.2 Risk factors for cancer of the uterine cervix, by strength of evidence

	Increases risk	Decreases risk
<i>Convincing or probable</i>	Infection with "high-risk" types of genital human papilloma viruses (HPV) ^{1,2}	
	Tobacco smoking ^{3,4}	
	Combined oestrogen-progestogen oral contraceptives ^{4,5}	
	High parity ⁴	
	Low socio-economic status ⁶	

¹ "high-risk" HPV types include 16, 18, 31, 33, 35, 39, 45, 51, 56, 58, 59, 66; ² International Agency for Research on Cancer, 2007a; ³ International Agency for Research on Cancer, 2004b; ⁴ Castellsagué and Muñoz, 2003; ⁵ International Agency for Research on Cancer, 2007b; ⁶ Faggiano et al, 1997

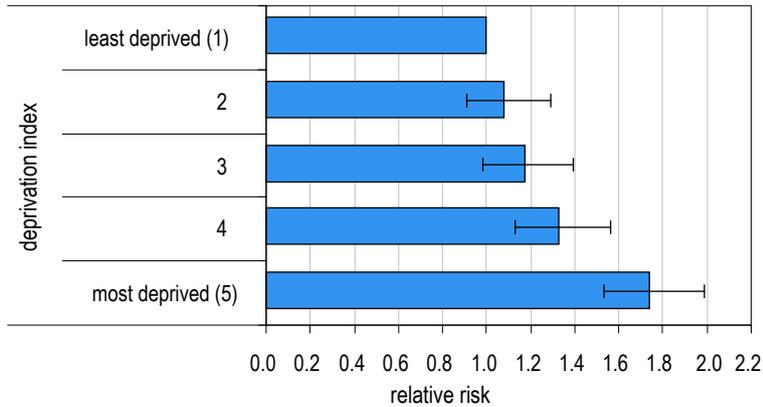
Numerous strains of human papilloma viruses (HPV) infect the genital squamous epithelia. Some strains (known as "low-risk") cause genital warts while other strains (known as "high-risk") cause cervical cancer (International Agency for Research on Cancer, 2007a). The association between cervical cancer and these high-risk types of HPV infection is so strong that HPV is considered to be a necessary cause of the disease (Bosch et al, 2002). Infection with high-risk HPV is very common, and most women who have been sexually active will be infected at some time during their lifetime (Bosch et al, 2008). In Ireland, studies of women attending for cervical smears have reported that prevalence of high-risk types is approximately 20% (Keegan et al, 2007, McInerney et al, 2008). In most women, infection causes no symptoms and clears naturally within a few months. However, some women become re-infected and the virus persists; it is susceptibility to persistent infections which is thought to increase risk of developing cervical lesions. The factor associated most consistently associated with risk of genital HPV infection is number of sexual partners (Winer and Koutsky, 2004).

Numerous studies have reported that smoking increases risk of cervical cancer, and recent studies show that the effect of smoking is not diminished by adjusting for HPV infection. These findings have led the International Agency for Research on Cancer to conclude that there is a causal relationship between smoking and squamous cell carcinoma of the cervix (International Agency for Research on Cancer, 2004b).

Risk of cervical cancer is raised in women who have used combined oestrogen-progestogen oral contraceptives and also increases with increasing parity. Risk is also raised in women of lower socio-economic status. While partly a function of variations in exposure to risk factors, this also reflects social class differences in access to cervical smear tests or participation in organised screening programmes (Segnan, 1997).

14.4 Electoral district characteristics and cancer incidence

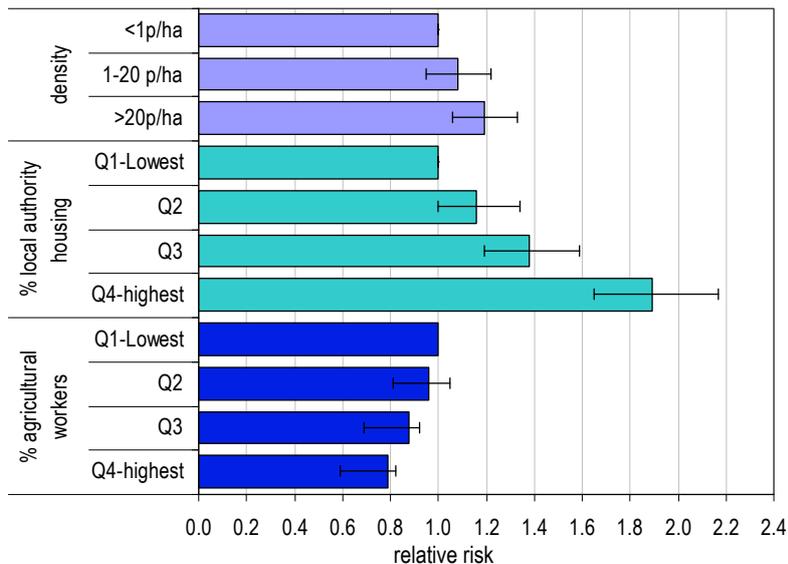
Figure 14.3 Adjusted relative risks of cervical cancer by deprivation index: females



Adjusted for population density

There was a strong and significant relationship between deprivation and cervical cancer incidence (figure 14.3). The incidence rate in the most deprived areas was more than 70% higher than in the most affluent (RR=1.74, 95% CI 1.53-1.99)

Figure 14.4 Adjusted relative risks of cervical cancer by area characteristics: females



All variables mutually adjusted except % of agricultural workers (not adjusted for density)

There was an association between cervical cancer and population density, but this was relatively modest (figure 14.4); risk was around 20% higher in the most populated, compared to the least populated, areas (RR=1.20, 95% CI 1.06-1.33).

Of the other socio-demographic variables studied, local authority housing was associated with cervical cancer risk. The areas with the highest proportion of local authority housing had an incidence rate almost 90% greater than those with the least local authority housing.

Socio-economic variation

The strong relationship between deprivation (and other markers of socio-economic status, such as proportion of local authority housing) and cervical cancer observed here is consistent with studies in many other countries. It is likely to be due to several reasons, including variations in exposure to risk factors (notably high-risk HPV infections and smoking), variations in exposure to risk factors for HPV (such as number of sexual partners) and differences in access to, or uptake of, smear tests. These explanations probably also account for the more modest relationship between population density and cervical cancer incidence.

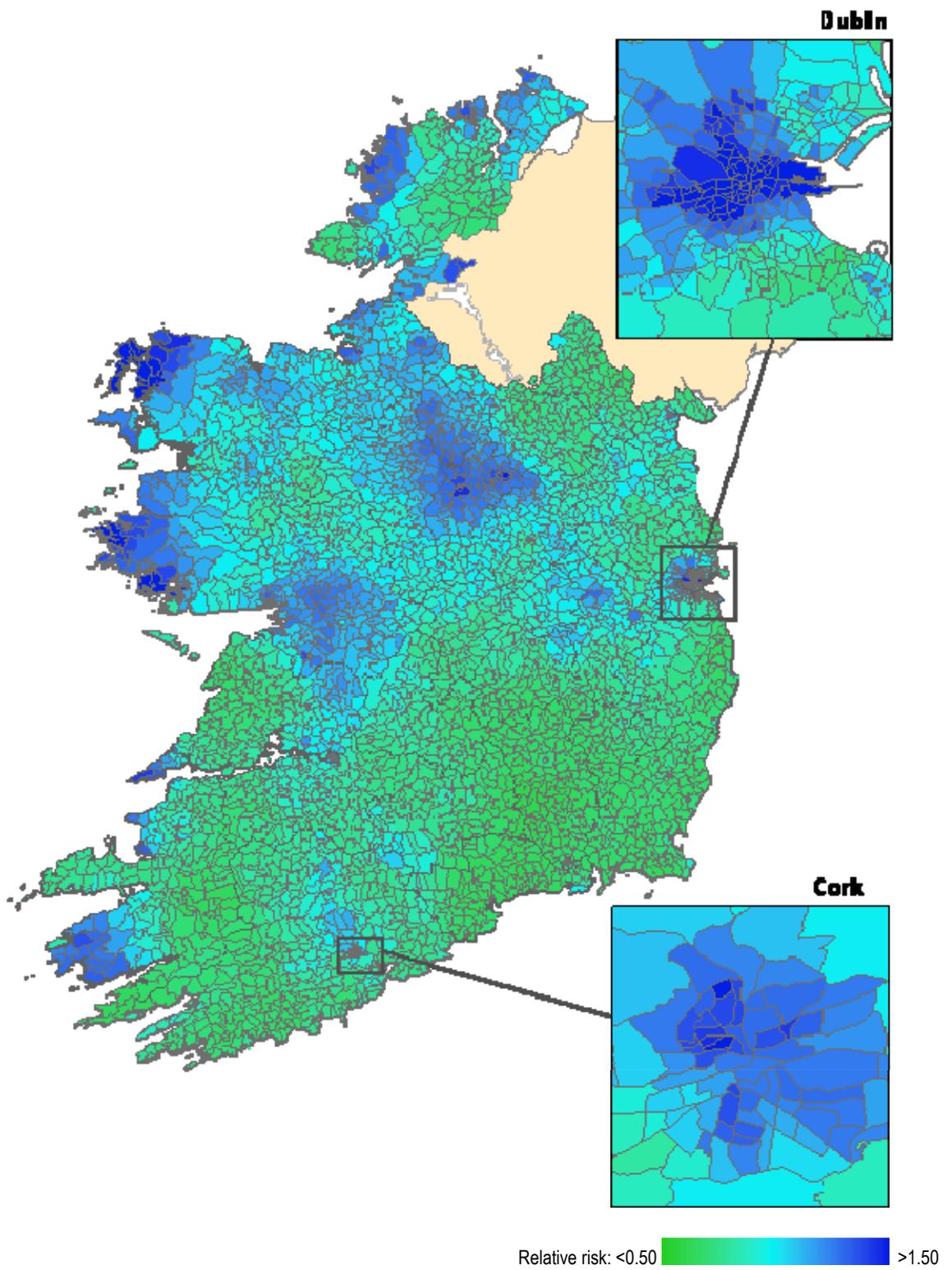
14.5 Mapping and geographical variation

Geographical variation

The areas of highest incidence of cervical cancer were concentrated in and around Dublin and in a broad band down the eastern side of the country from Dublin, through Kildare and Wicklow, to Wexford (map 14.1). There was another less concentrated band of areas of higher incidence running through the middle of the country, from north to south. Lower incidence was observed in the southwest, in counties Cork and Kerry, as well as in Donegal in the northwest. In Dublin and Cork, the highest incidence areas were in the north of both cities, corresponding to areas with higher deprivation and higher densities of local authority housing.

In comparing the distribution of cervical cancer with that of poverty (measured by income) from the SLÁN survey (Appendix 1), there was some correspondence between the areas of high incidence and those of high poverty in the east and midlands, but not in the west. There was no clear relationship to smoking prevalence (Appendix 1), however, some similarities with lung cancer incidence in women were observed (map 7.3).

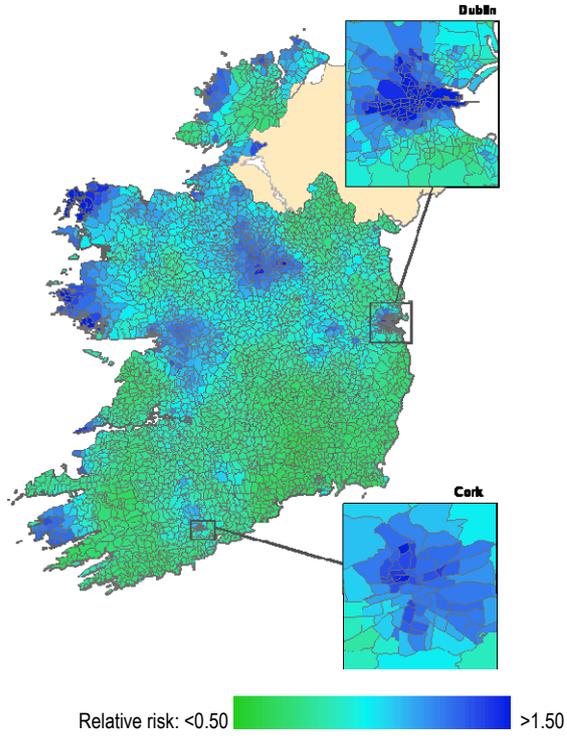
Map 14.1 Cancer of the uterine cervix, smoothed relative risks: females



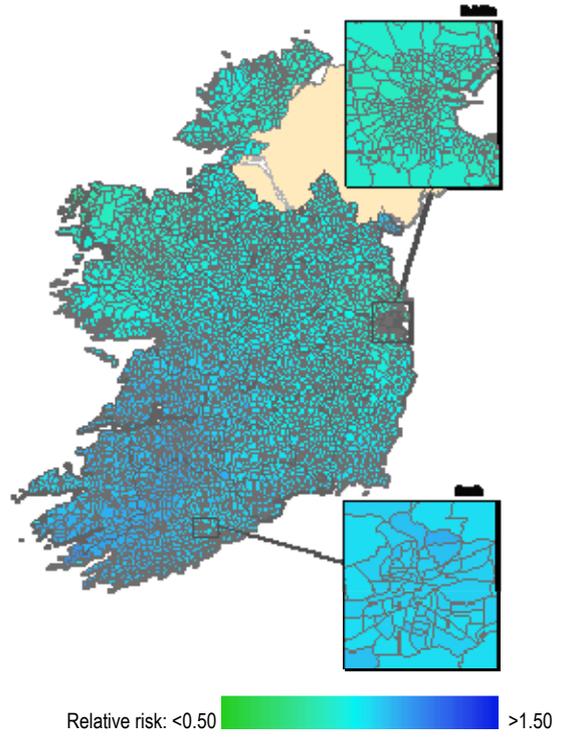
15 Geographical distribution of other cancers

Maps 15.1-15.7 show the smoothed relative risks for seven other cancer sites. For cancers of the brain and central nervous system, no clear geographical variation was evident. Cancers of the pancreas, corpus uteri and leukaemia had a slightly higher incidence in the southwest, lymphoma and cancers of the kidney were more common in the east and incidence of ovarian cancer was slightly higher in the southeast. However, all of these patterns were weak and no inference can be drawn from them.

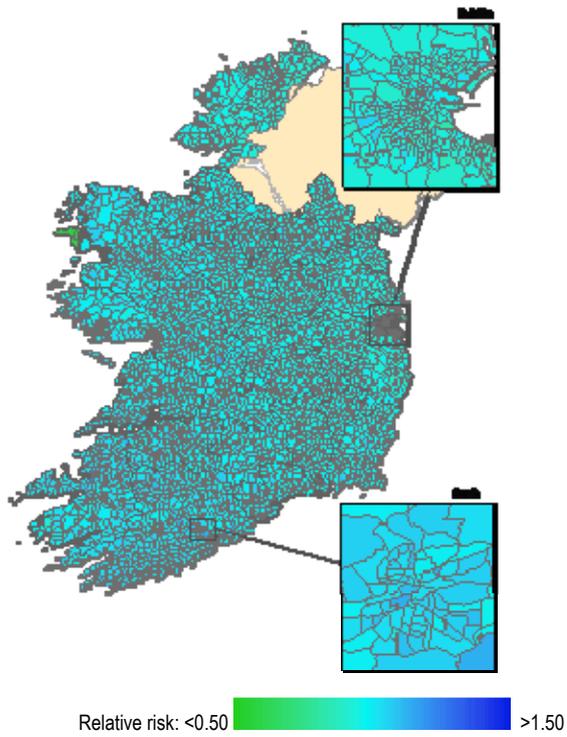
Map 15.1 Lymphoma, smoothed relative risks: both sexes



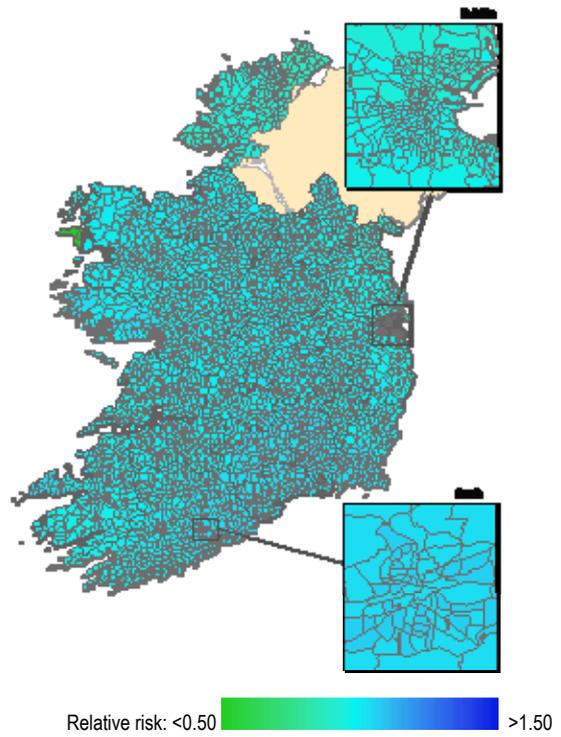
Map 15.2 Leukaemia, smoothed relative risks: both sexes



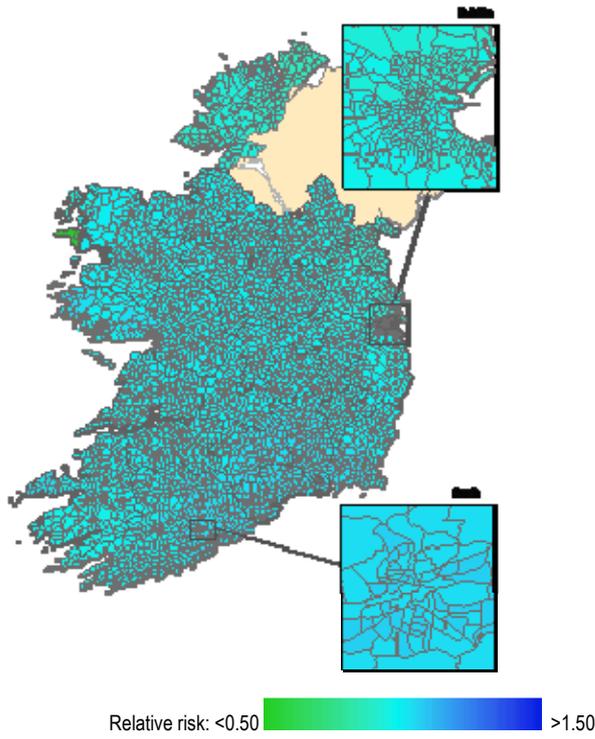
Map 15.3 Pancreatic cancer, smoothed relative risks: both sexes



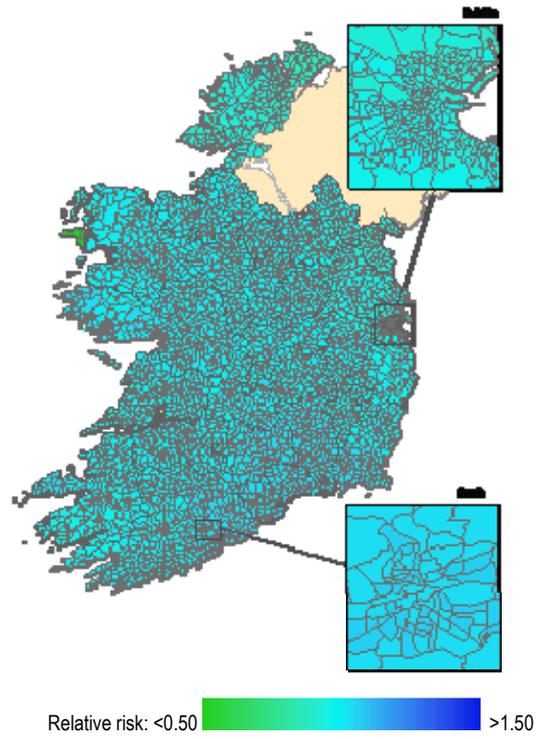
Map 15.4 Ovarian cancer, smoothed relative risks: females



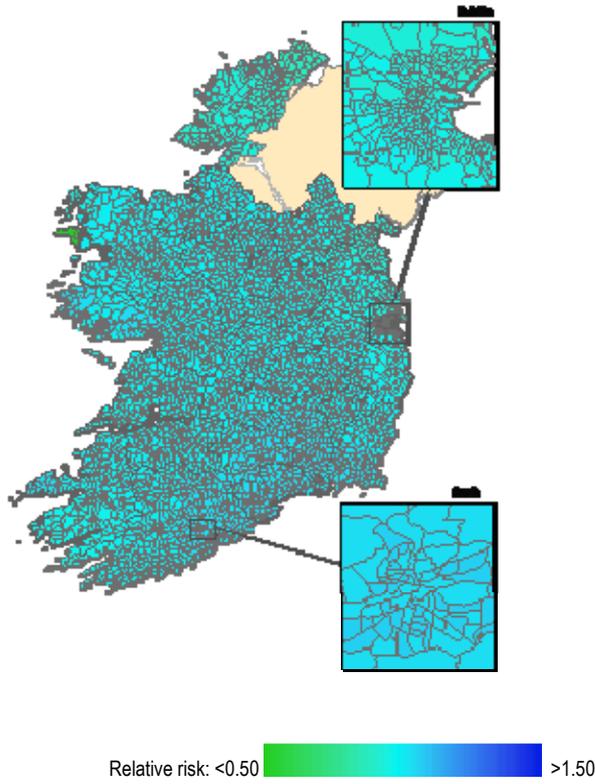
Map 15.5 Brain and central nervous system cancer, smoothed relative risks: both sexes



Map 15.6 Kidney cancer, smoothed relative risks: both sexes



Map 15.7 Cancer of the corpus uteri, smoothed relative risks: females



16 Discussion

Geographical variations

There are geographical variations in the risk of cancer across Ireland. For some cancers, these patterns are quite striking, while for others they are less marked. Although some similarities were apparent (and these are discussed further below), the observed geographical variations were, in the main, different for different cancers. Generally, for those cancers that affect both sexes, the geographical distribution was similar for males and females. However, it must be kept in mind that these variations in risk do not mean that the spatial location itself causes cancer, but rather they are likely to reflect socio-economic differences in the population, geographical differences in exposure to risk factors and, for some cancer sites, variations in access to, or uptake of, screening or other cancer services.

Genetic, environmental and lifestyle risk factors

Several strands of evidence suggest that there are genetic differences between different parts of Ireland (Hill et al, 2000, Dolan et al, 2005 and references therein). Although there is a genetic component to the aetiology of many cancers, it is very unlikely that variations in genetic make-up alone could explain the geographical (and socio-economic) variations in cancer incidence seen in this report. Once specific genetic syndromes are discounted, inherited genetic factors make a minor contribution to susceptibility of most types of "sporadic" cancer (Lichtenstein et al, 2000). The seminal work by Doll and Peto almost 30 years ago estimated that four in every five cancers were due to lifestyle or environmental factors (Doll and Peto, 1981). Although more recent estimates suggest that the percentage of the cancer burden due to *well established* behavioural and environmental factors is somewhat lower (Danaei et al, 2005, International Agency for Research on Cancer, 2007d, Boffeta et al, 2009), the overwhelming importance of these factors in cancer aetiology is clear. In addition, while it is recognised nowadays that most diseases, including cancer, are a result of complex gene-environment interactions (Khoury et al, 2005), it is exposure to lifestyle factors which remains of paramount importance - after all, germline mutations or polymorphisms are determined at birth, but lifestyle exposures are potentially modifiable throughout life.

Smoking

The observed higher incidence of lung cancer in cities and in the east of the country must reflect geographical variations in smoking habits, since 90% of lung cancers are caused by smoking (International Agency for Research on Cancer, 2004b). Smoking is also a major risk factor for cancers of the bladder and head and neck and, to a somewhat lesser extent, for cancers of the stomach, oesophagus and cervix. Therefore, some similarities between the geographical distributions of these cancers and lung cancer might have been expected. For bladder cancer, where two-thirds of cases in men and one-third in women are considered to be due to smoking (Brennan et al, 2000, Brennan et al, 2001), the maps showed some similarities to those for lung cancer, but did not fully correspond. For head and neck cancer, where up to 70% of cases may be due to smoking (Hashibe et al, 2009), there were again some similarities with the distribution of lung cancer, but also some differences. These observations suggest that other important risk factors probably play a role in the geographical distribution of bladder and head and neck cancer in Ireland. The distributions of cancers of the stomach, oesophagus and cervix were much less similar to those of lung cancer, pointing to the importance of other risk factors in these cancers.

Early detection and screening

There were some similarities in the patterns of incidence of breast and prostate cancer and of non-melanoma cancer and melanoma of the skin. The detection of all of these cancers is influenced by better health awareness and access to early-detection or screening. For prostate cancer, there was quite striking spatial variation in risk, with marked areas of higher incidence around the major urban centres, with the exception of Limerick. Within Dublin and Cork, incidence was higher in the more affluent areas of the cities. PSA testing is extensive in Ireland and there is evidence of widespread variations in practice between GPs (Drummond et al, 2009b). It seems likely that these variations are driving incidence of prostate cancer to some extent. Although the geographical variation in breast cancer incidence was not strong, there were some similarities with prostate cancer: those areas with higher incidence of prostate cancer also tended to have higher incidence of breast cancer. The higher breast cancer incidence around Dublin, where the national screening programme began, and similarities with the distribution of levels of private health insurance, suggests attendance for mammography has influenced the geographical distribution of breast cancer.

Skin cancers

As regards melanoma and non-melanoma skin cancers, there were clear similarities in the spatial distributions, with patches of higher incidence around Dublin and Cork, and on the southeast coast. This is not surprising given that exposure to UV radiation is the major risk factor for both lesions (International Agency for Research on Cancer, 1992, International Agency for Research on Cancer, 2001). However, there were quite widespread areas of high incidence of non-melanoma skin cancer in the southwest, which do not seem to be explained by patterns of sun exposure or occupation. This suggests that other factors may play a role in non-melanoma skin cancer - either influencing disease risk *per se*, or influencing likelihood of detection (and registration).

Cervical cancer and HPV

Quite striking geographical variations in incidence of cervical cancer were observed, with a distinct area of higher risk extending westwards from Dublin, and south towards Wexford. The biggest difficulty in interpreting these patterns is the lack of information on HPV prevalence in different parts of Ireland. Preliminary data from the CERVIVA research programme suggest that prevalence of HPV high-risk types among women having smears is slightly higher in the east (Leinster) than the west (Connacht) of the country (McInerney et al, 2008), which would be consistent with the observed distribution of cervical cancer.

Gastro-intestinal cancers

There are some similarities in the factors thought to be involved in cancers of the upper gastro-intestinal tract (e.g. tobacco, alcohol, diet, aspirin and non-steroidal anti-inflammatory drugs, *H pylori*). However, the maps for stomach and oesophageal cancer were quite different, with a clear area of higher risk in the northeast for stomach cancer and higher risk in the south for oesophageal cancer. These differences probably reflect, to some extent, spatial variations of risk factors specific to the individual cancers (e.g. diet rich in salted food for stomach cancer). However, the interpretation of the geographical patterns of these two cancers is actually very difficult, since both comprise distinct sub-types of cases. In terms of oesophageal cancer, the risk factors of squamous cell carcinoma and adenocarcinoma are not the same. The epidemiology and aetiology of distal, intestinal-type, stomach tumours and proximal, diffuse-type, tumours of the gastric cardia (which are also assigned to the ICD10 code for stomach)

also differ (Crew and Neugut, 2006); indeed, the latter group shares some similarities with oesophageal adenocarcinoma. Mapping such distinct sub-types together would tend to diminish spatial differences. Further analyses of specific sub-types might be informative.

The geographical variation in the incidence of colorectal cancer was not as striking as for some other cancers. Having said that, there were areas of higher incidence in and around Cork and Dublin, for both sexes, and in the northwest for women and in the northeast for men. The lack of a strong association with deprivation suggests that other factors must explain the spatial variation. The acknowledged importance of lifestyle factors in the aetiology of colorectal cancer makes it likely that the variations are due to the combined influence of geographical variations in obesity, levels of physical activity, diet, use of aspirin and other non-steroidal anti-inflammatory drugs, etc.

Deprivation and cancer incidence

All of the cancers analysed showed some association with deprivation, either positive (all malignant cancers combined and colorectal, lung, stomach, bladder, head and neck, cervical and oesophageal cancer) or negative (breast, prostate and non-melanoma and melanoma skin cancers). In general, the relative risk estimates for the most, compared to the least, deprived were relatively modest falling in the range 0.8-1.3. Stronger associations were seen for lung cancer in men (RR=1.72) and women (RR=1.56), head and neck cancer in men (RR=1.78), cervical cancer (RR=1.74), and melanoma (RR in men 0.66, in women 0.64).

The patterns are generally consistent with those reported from the UK using area-based measures of deprivation (Quinn et al, 2005). They are also consistent with patterns reported in other countries for a range of other measures of socio-economic status at the level of the individual, including occupation and social class, education, housing tenure and income (Faggiano et al, 1997).

The possible explanations for socio-economic variations in cancer incidence (and mortality) have been extensively discussed elsewhere (see, for example, Kogevinas et al, 1997). The associations are, in the main, likely to be explained by socio-economic variations in exposure to cancer risk factors and cancer preventive behaviours, such as screening. Social class variations in occupational exposures make a (relatively minor) contribution to the socio-economic gradient for some cancers (Boffetta 1997), but for most cancers, the most important explanation is socio-economic variation in lifestyle risk factors such as smoking, alcohol, diet and obesity. These variations are evident both in Ireland (Morgan et al, 2008) and internationally (Bolton-Smith et al, 1991, Møller and Tønnesen, 1997, Erens, 1998, Huisman et al, 2005, Mackenbach et al, 2008, British Heart Foundation, 2009) and generally show that the groups of lowest socio-economic status have higher prevalence of smoking and obesity and lower consumption of fruit and vegetables. In addition, and of relevance to some cancers, there are socio-economic differences in reproductive behaviour and use of exogenous oestrogens (dos Santos Silva and Beral, 1997, Shah et al, 2001, Layte et al, 2006, Løkkegaard et al, 2007, Parazzini et al, 2008). Moreover, socio-economic variations in sexual behaviours have also been described (de Sanjosé et al, 1997), which suggest that there may also be variations in prevalence of HPV. In terms of other infections, prevalence of *H pylori* infection is inversely related to socio-economic status (Murray et al, 1997). Any attempts to address the socio-economic variations in cancer risk in Ireland will require initiatives to tackle socio-economic differentials in these well established cancer risk factors.

Uptake of screening is generally lower among those of lower socio-economic status (Segnan, 1997), even in settings where screening is offered in the form of an organised programme for which the participant does not have to pay (for example, as in the NHS in the UK; Maheswaran et al, 2006, Sabates and Feinstein, 2006, Weller et al, 2007). Avoiding similar patterns in Ireland will be a challenge for the newly established national screening programmes, BreastCheck and CervicalCheck.

It is worth noting that the cancers which were positively associated with deprivation did not all have the same geographical pattern, and the same was true for the cancers which were negatively associated with deprivation. So, while deprivation is related, in a broad sense, to cancer incidence in Ireland, it does not fully explain the geographical variations observed in this report. As a caveat to this, it should be remembered that, since the majority of the most deprived areas are located in the main cities, the associations with deprivation are dominated by areas of high population. In contrast, most of the maps are dominated by incidence patterns in areas of low population, outside of the main cities.

Urban/rural variations in cancer incidence

With the exception of prostate cancer, all of the cancers considered in this report were significantly associated with population density. More densely populated areas (those with a population of >20 persons/ha) consistently had a higher risk of cancer than those that were sparsely populated (<1 persons/ha). Some of the observed associations were reasonably strong: relative risks were 1.4 or higher for cancers of the stomach, bladder, and lung. There are likely to be several reasons for these findings. There is undoubtedly some confounding between "deprivation" in its most general sense and population density, since many of the areas which would be classified as most deprived are in urban areas (and the deprivation indices provide a less good marker of socio-economic status in rural areas - see below). This means that, in part, the relationships with population density simply reflect "deprivation" and the related associations with cancer risk factors, as discussed above. Interestingly, for some cancers which were positively associated with deprivation, the associations with population density were slightly stronger than those with deprivation (e.g. bladder and stomach cancer, and lung cancer in females).

However, the relationship between deprivation and urban/rural status cannot be the entire explanation for the associations between cancer and population density since, for several cancers that were inversely associated with deprivation (e.g. breast cancer, and melanoma and non-melanoma skin cancer), incidence was higher in more densely populated areas. Urban/rural variations in risk factors for these cancers have been suggested by studies in other countries. For example, accessibility of (or access to) air travel correlates strongly with melanoma incidence in the USA and Norway (Agredano et al, 2006) and, in Sweden, more foreign travel was considered to be the explanation for the higher melanoma rates in cities compared to the countryside (Eklund and Malec, 1978). In Denmark, use of HRT (which is aetiologically relevant to breast, uterus and colorectal cancer, and may be involved in ovarian cancer) was higher amongst women resident in urban areas (Løkkegaard et al, 2007). Whether there are urban/rural variations in cancer risk factors in Ireland is not known.

Research in England and Northern Ireland has demonstrated that access to health services is worse, and rates of health service utilisation are lower, in rural than urban areas (Gilthorpe and Wilson, 2003, O'Reilly et al, 2007). Specifically, uptake of breast cancer screening has been shown to be lower amongst women in more rural areas

in both the USA (Doescher and Jackson, 2008) and Europe (Maheswaran et al, 2006, Polasek et al, 2007). Data such as this suggests that our findings could also be due to differences in access to, or utilisation of, cancer screening or early detection services between urban and more rural parts of Ireland.

Other area characteristics and cancer incidence

Elderly living alone

For all cancer sites, with the exception of cervix uteri, risk of the disease was higher in areas with the highest proportion of elderly people living on their own. Although the risk estimates for the highest compared to the lowest quartile were less than 1.3, this factor was significantly related to almost every cancer. These findings are difficult to interpret, and several different explanations are possible. Firstly, the proportion of elderly living alone may simply be another marker of deprivation. However, positive associations with elderly living alone were also seen for cancers which are negatively associated with deprivation. Secondly, the group of elderly living alone may make greater use of health services and be consequently more likely to be diagnosed with cancer. However, recent studies from the UK have found that elderly people living alone have poorer self-reported health than elderly persons who do not live alone, and that those at risk of social isolation (for which the proportion of elderly living alone may be a marker) do not make greater use of medical services (Iliffe et al, 2007, Kharicha et al, 2007). This makes it unlikely that increased medical attention in this group would be the explanation for the findings. Thirdly, there may be something about those who live alone which places them at increased risk of cancer. The same UK studies also showed that elderly persons living alone have poorer diet, lower physical activity, more hazardous alcohol use and are more likely to be smokers, than those who do not live alone (Kharicha et al, 2007). This might either be a result of, or a contributing factor for (via shared lifestyles), the premature death of a spouse/partner. Either way, this suggests that the elderly living alone could be at greater risk of cancer by virtue of their lifestyle, at least in the UK. Whether the same variations in lifestyle are evident among older people in Ireland is not known. Finally, in terms of explanations, it is possible that the proportion of elderly living alone may be a proxy for some other unmeasured cancer risk factor.

Agricultural workers and other area-based measures of socio-economic status

Areas with a higher percentage of agricultural workers consistently had a lower risk of cancer. This was seen for all cancers, with the exception of prostate cancer. It is most likely that rather than conferring a lower risk of cancer *per se*, agricultural work is simply a marker for some other factor. One likely possibility is population density; the correlation between these two variables was very strong (correlation coefficient=-0.892; chapter 2).

The observed relationships between the other area-based characteristics and cancer risk - such as percentages of lower social class, unemployed, living in overcrowded housing, and early school leavers - tended to mirror the associations with deprivation. This was not surprising, since some of these are included in the composite deprivation index. What is more interesting, perhaps, is that there were differences between cancers in the individual area-based characteristics which were related to risk.

Strengths and limitations of the analysis

The report presents, for the first time, a detailed analysis of the geographical variation in cancer across Ireland. In order to facilitate interpretation of the geographical patterns, it presents the main available data on diet and other aspects of lifestyle, together with the maps of cancer incidence. A major strength is that it also explores how cancer incidence varies according to various area-based measures of socio-economic status. Although these analyses have limitations (which are discussed below), they extend knowledge about the socio-economic variations in cancer in Ireland. Information on income, employment or other indicators of socio-economic status is not available at an individual level to the Registry, as this information is rarely available from medical records, and linkage to other sources of information on individuals (e.g. census or income tax data) is not permitted.

Ecological analyses

The major limitation of the type of analysis contained in this report is that it is ecological - neither the cancer incidence nor the area characteristics studied necessarily apply to the individuals resident within the areas (Morgenstern, 1995). For example, individuals may live in an area which has a higher proportion of manual workers, without being a manual worker themselves. This means that there is no guarantee that associations at area level translate to associations at the level of the individual. Using small-area data (as was done in this report), as opposed to regional or county-specific data, would be expected to reduce ecological bias but does not exclude it. This should be borne in mind when interpreting the patterns described in the report.

The assessment of deprivation

Many studies, in a variety of different countries, have shown a link between “deprivation”, measured at an area level, and cancer incidence or survival (see, for example, Faggiano et al, 1997, Kogevinas and Porta, 1997, Singh et al, 2003, Coleman et al, 2004, Dejardin et al, 2006, Shack et al, 2007, Shack et al, 2008, van der Aa et al, 2008, Yu et al, 2008). Where such studies have been possible, poverty, measured at the level of the individual, has been shown to have the same associations. It is not clear, therefore, if measures of deprivation at an area level are merely proxies for individual deprivation, or whether there are also area-specific factors. In addition, it is well recognised that there may be differences in what deprivation indices measure in urban and rural areas (Haynes and Gale, 2000, Gilthorpe and Wilson, 2003). Cook and colleagues have illustrated the problems of using these compound (e.g. deprivation score) and secondary (e.g. % manual workers, % without a car) indices in Ireland (Cook et al, 2000). Even in areas with high unemployment, the majority of residents in any ED are employed, and in areas where housing is poor, most residents are adequately housed. Therefore, these measures probably indicate no more than a risk of poverty. Moreover, while various measures of deprivation such as unemployment and low educational attainment are highly correlated in urban areas, where people tend to be segregated by income, these relationships are weak in rural areas, which typically have a more heterogeneous population. Therefore, while measures of “deprivation” have some predictive, if not explanatory, value in urban areas, this is much less so in the country. Therefore, although we describe relationships between socio-economical characteristics and cancer in this report, care must be taken not to over-interpret these.

Exposure to cancer risk factors

A final limitation relates to the available data on exposures to risk factors. Cancer is a complex multi-factorial disease and arises as a result of prolonged exposure to a particular - or more likely several - risk factor(s). Therefore, what is relevant in terms of interpreting current patterns of cancer incidence are patterns of exposure to risk factors 20 or more years ago. However, the available data relate to current (or recent) patterns of exposure, and these may not reflect patterns in past years. This is one reason why the geographical distribution of some cancers does not correlate particularly well with the distribution of the known risk factors.

It is perhaps worth commenting on a more general limitation as regards cancer risk factors. A 2007 study by the International Agency for Research on Cancer estimated that 40% of cancers in France were attributable to known environmental or lifestyle risk factors including smoking, alcohol, obesity, lack of physical activity, exogenous hormones, etc (International Agency for Research on Cancer, 2007d). Since only a relatively small proportion of the remainder are likely to be due solely to known genetic factors, this means that there are still major gaps in knowledge about cancer aetiology. In light of this, it is not surprising that many of the geographical and socio-economic patterns described in this report are unexplained.

Finally, this report did not set out to investigate cancer risk in relation to specific geographical locations, such as industrial sites, landfill sites, etc. As alluded to in chapter 2, different statistical approaches are required for methods for analysing cancer patterns around such "point sources". Understandably, those who live in proximity to such locations often have concerns about the potential impact on their health. Many of the studies that have been undertaken on cancer risk (and other health outcomes) around such sites have methodological limitations. To date, the evidence does not support a causal relationship between risk of cancer and residence close to landfill sites (Jarup et al, 2002), sites of toxic waste (Russi et al, 2008) or locations of mobile phone transmission masts (Wood, 2006).

Further work

This is the first report on spatial distribution of cancer in Ireland. The National Cancer Registry intends to build on this, and a range of further analyses are planned. These include:

- exploration of spatial patterns over time, which would provide useful insights on the impact of prevention, screening or other population interventions on the long-term risk of cancer;
- mapping sub-groups of cancers (e.g. basal and squamous cell non-melanoma skin cancers, squamous cell carcinomas and adenocarcinoma of the oesophagus), which might provide further clues as to factors which explain geographical variations;
- joint disease mapping (i.e. mapping several cancers simultaneously), which would allow the impact of shared risk factors to be explored (Downing et al, 2008);
- mapping cancer incidence in small areas across the whole island of Ireland, which may shed more light on possible explanations for geographical variations, particularly in those areas bordering on Northern Ireland;

- exploration of geographical and socio-economic variations in survival and mortality, which would provide a better understanding of cancer disparities in Ireland.

Research and data recommendations

Areas with unexplained high risk

As regards the specifics contained within this report, it seems obvious that the areas with higher than average incidence of particular cancers, which cannot be readily explained in terms of known risk factors, deserve further study to determine what factor(s) may be driving the observed geographical patterns. Examples include the areas of higher incidence of stomach cancer in the northeast and far northwest of the country; the strip of higher incidence of bladder cancer down the east coast and an area in the northwest; the diagonal split across the country into areas of higher (south and east) and lower (north and west) incidence of oesophageal cancer; the increased risk of colorectal cancer around Cork; and the various patches of higher incidence of melanoma and non-melanoma skin cancer around the coastline, particularly in the west of the country.

Further study is needed of areas with unexplained higher than average cancer incidence.

Patterns of exposure to cancer risk factors in Ireland

More generally, it is perhaps inevitable that analyses such as these generate more questions than they answer. This is in part due to the limitations of the methodology itself (discussed above) and in part due to a lack of knowledge about cancer aetiology. Having said this, it is worth noting that much is known about which factors are associated with increased risk of cancer and which are related to decreased risk. However, the available data on patterns of exposure to cancer risk factors in Ireland, and how these vary across the country and in different sub-groups of the population, is limited. For example, even in a survey as detailed as SLÁN, which involved interviewing more than 10,000 individuals (Morgan et al, 2008), the number of persons in each area was too small to permit detailed spatial patterns in lifestyle behaviours and other risk factors to be explored. For some important cancer risk factors, such as use of exogenous oestrogens like HRT, or exposure to HPV, there seems to be an almost complete lack of data at the national level, never mind by age, socio-economic status, and geographical area.

This lack of data makes it difficult to confirm the extent to which these associations described in this report can be explained by known risk factors, or might be due to other factors.

More data is needed on patterns of exposure to well-known cancer risk factors in the population of Ireland, and on how these patterns vary by age, sex, socio-economic status, geographically, and over time.

Health service utilisation, and data availability, access and linkage

The socio-economic and geographical variations described in this report are likely to be partly influenced by issues related to healthcare utilisation, for some cancers at least. For example, variations in non-melanoma skin cancer might be due to differences in referral to dermatology clinics, which in turn would be influenced by availability of dermatology services, and variations in GP referral practice. However, little is known about patterns of utilisation of, or access to, either primary or tertiary care services in Ireland.

Similar comments apply to uptake of mammography and cervical smear testing. Both of these were commonly done before the national screening programmes were established, but little, if anything, is known about which groups of the population were accessing these services and - perhaps more importantly - which groups were not.

In some instances, data which would help interpret the patterns in this report is probably already collected, but simply cannot be, or has not been, accessed or collated on the national level. For prostate cancer, for example, it seems likely that differences in PSA testing practices and uptake underlie the observed variations between deprivation categories and across the country. Over the past few years, the National Cancer Registry has made extensive efforts to collect detailed data on PSA testing, but this has been thwarted by a range of difficulties, including problems with IT systems and data ownership (Drummond et al, 2009a).

A related issue concerns linkage of routinely-collected data. In many countries linkage of, for instance, individual-level census or occupational data with cancer registrations is taken for granted. It provides information of much higher quality than that which is available at the area level, and generates datasets with great power and versatility, which can be used to investigate the role of socio-economic and other factors in cancer risk, health service utilisation by cancer patients, factors influencing treatment, patient outcome, etc (see, for example, Dalton et al, 2008, Dal Maso et al, 2009, Dalton et al, 2009, Hagel et al, 2009, Lindbohm et al, 2009, Thygesen et al, 2009, Reeve et al, 2009, Tetsche et al, 2008). In Ireland, however, due to legal restrictions, this type of analysis cannot be carried out at present.

Developments such as the Health Atlas (Health Service Executive, 2009) - which is bringing together the diverse sources of health data in Ireland and making it publicly available - are to be welcomed, but on their own they are not sufficient.

Greater understanding is needed of patterns of healthcare access and utilisation in Ireland, and how these vary. Data to facilitate such analyses should be collected nationally in a standardised form.

Linkage of routinely collected data should be permitted, with appropriate - but not overly restrictive - provisos regarding confidentiality.

Knowledge and awareness of cancer risk factors in the population

One of the major drivers of utilisation of health services, particularly preventive services such as screening, is likely to be knowledge and awareness of cancer risk factors, and indeed of early signs and symptoms of the disease. There has been very little research into the knowledge, awareness, attitudes and beliefs of the Irish

population about what causes cancer, how it can be prevented, and what the signs of cancer are (McMenamin et al, 2005, FitzGerald et al, 2008, Harewood et al, 2009). How levels of knowledge, for example, vary by socio-class, geography, age, etc, and how they relate to health behaviours (e.g. participation in screening, smoking, etc) and help-seeking practices (e.g. attending the GP if concerned about symptoms), is unknown. Without such knowledge, individuals cannot be expected to take personal responsibility for addressing their own exposures, or indeed to be sufficiently aware of cancer warning signs to present early for investigation. Related to this, it is interesting that public health campaigns to encourage healthy lifestyle behaviours (e.g. physical activity) in Ireland, have tended to focus on benefits in terms of cardiovascular prevention, rather than cancer. An approach which stresses the many and diverse benefits of lifestyle change might be more successful, and might serve to increase awareness of risk factors for cancer.

Research is needed into levels of awareness and knowledge of cancer risk factors in Ireland, and how these vary by age, sex, socio-economic status and geographical area.

To help raise awareness of cancer risk factors among the public, "healthy lifestyle" campaigns and initiatives should make clear the links between lifestyle and cancer.

Cancer aetiology

Having said all of the above, it is worth remembering that for some cancers, relatively little is known about the disease aetiology, and further investigation of risk factors is warranted; prostate cancer is a prime example. There have been very few aetiological studies in Ireland. Those reported to date are limited to oesophageal adenocarcinoma (Anderson et al, 2008), breast cancer (Colleran et al, 2009) and lymphomas and multiple myeloma (Boffetta et al, 2008b) and a study of pancreatic cancer is underway involving the National Cancer Registry and Queen's University Belfast (Ireland-Northern Ireland-National Cancer Institute Cancer Consortium, 2009). While it is worth bearing in mind that few cancers would be sufficiently common in a small country like Ireland to make "stand-alone" case-control studies feasible or worthwhile, joining international collaborations is a realistic possibility, assuming funding is available. The oesophageal, pancreatic and lymphoma studies mentioned above are all part of international consortia. This approach offers advantages, both in terms of advancing understanding of the causes of cancer in Ireland and elsewhere, and of providing some local information on exposures to cancer risk factors in the general population. The International Agency for Research on Cancer, which Ireland has recently joined, offers exceptional potential for this type of study.

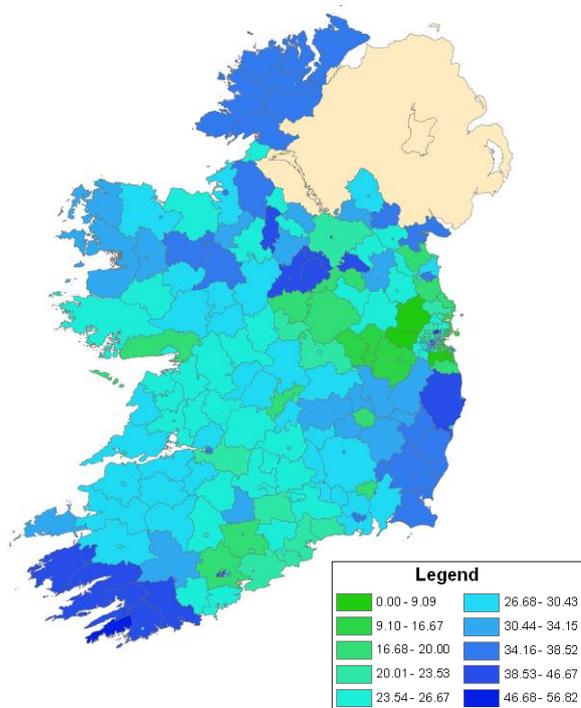
Studies of aetiological factors for several cancers are warranted. Ireland could best contribute to these by joining international collaborations.

17 Conclusions

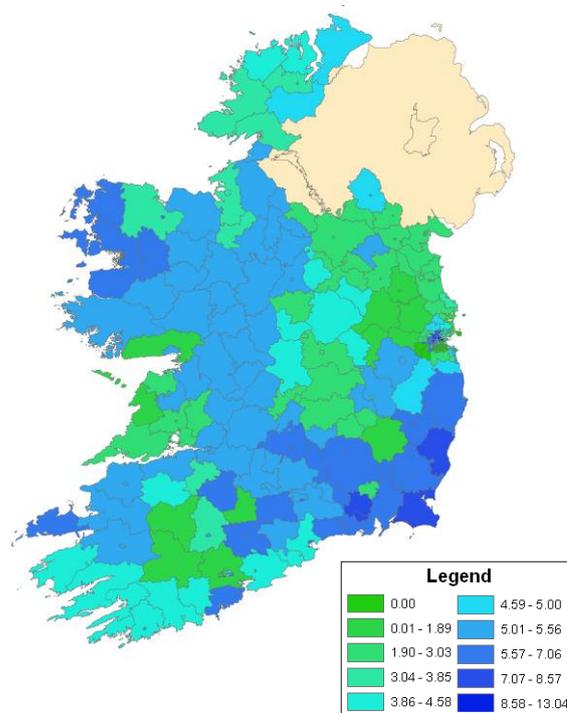
This report has revealed geographical and socio-economic variations in cancer risk in Ireland. These are likely to reflect differences in social, economic, cultural and environmental differences between subgroups of the population. Although risk factors for cancer are not all well-defined, nor modifiable (e.g. family history, genetic background), it is likely that many of the differences observed reflect a combination of variations in well-known risk factors (such as tobacco smoking, alcohol drinking, obesity, diet, sexual behaviour, etc), and variations in participation in screening, health awareness and access to cancer services. Since these factors are potentially modifiable, there is considerable potential for reducing cancer incidence in Ireland and eliminating the disparities described in this report.

Appendix 1 Exposure data from the SLÁN survey¹

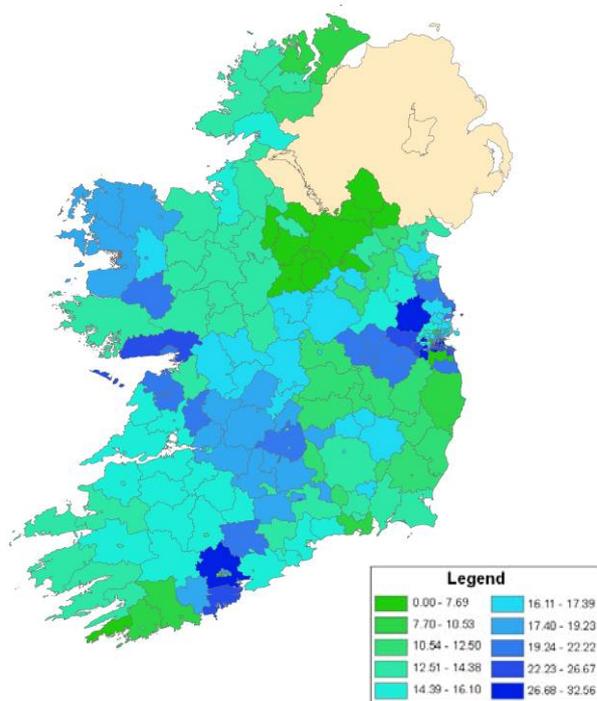
Map APP1.1 Percentage of population below 60% of median equivalised income



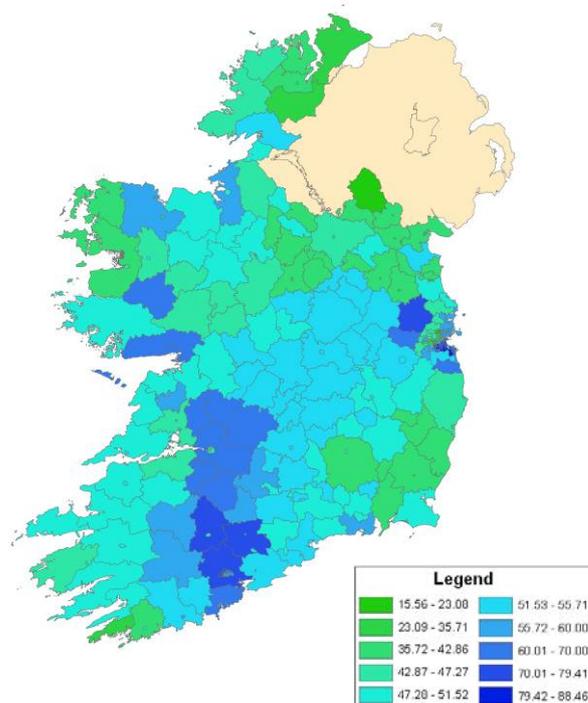
Map APP1.2 Percentage of population in social class 6



Map APP1.3 Percentage of population in highest quintile of household equivalised income²



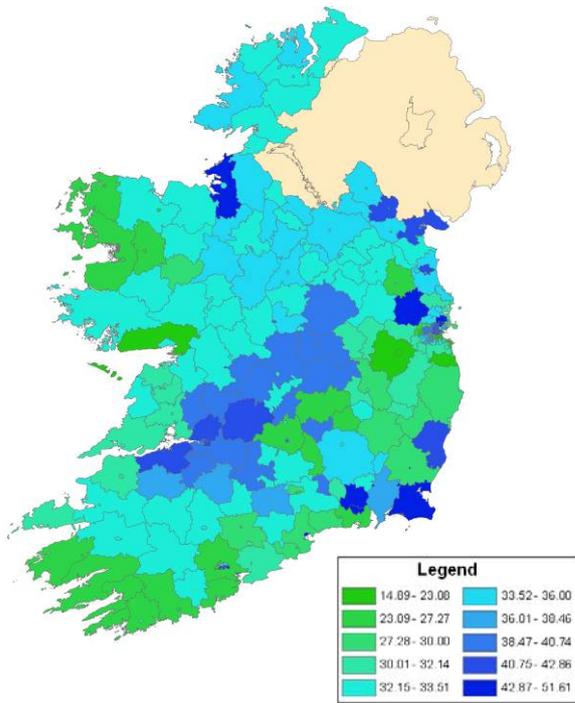
Map APP1.4 Percentage of population covered by private health insurance



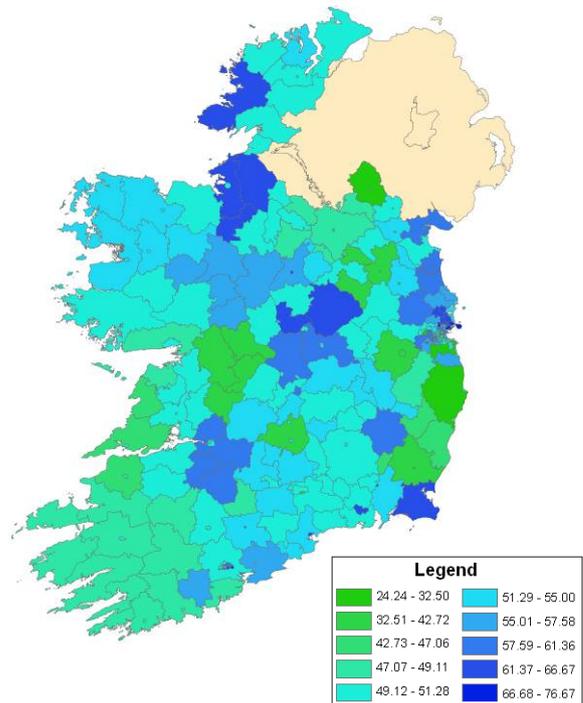
¹ Data kindly provided by the SLÁN research group (<http://www.slan06.ie/team.htm>; Morgan et al, 2008)

² Modified OECD equivalence scale

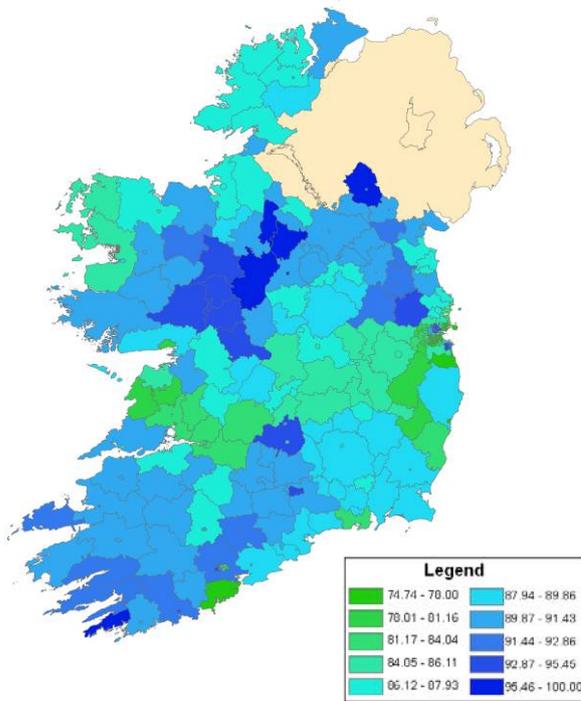
Map APP1.5 Percentage of population with low fruit and vegetable intake (<5 servings daily)



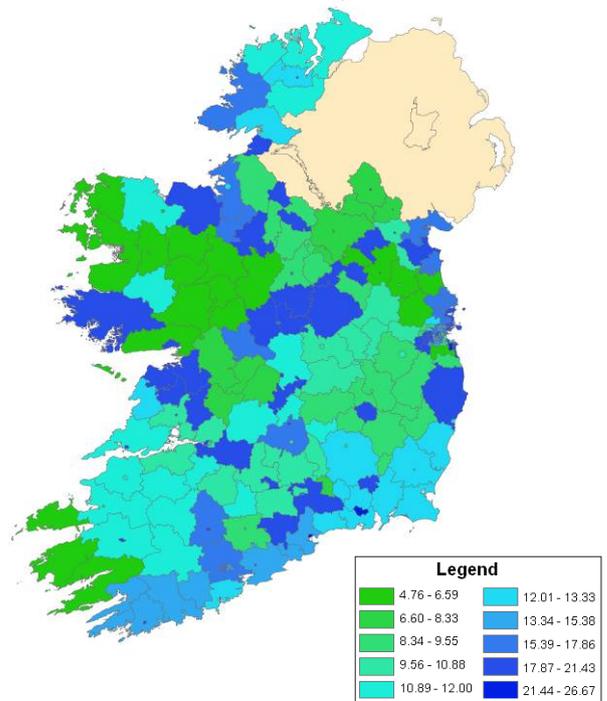
Map APP1.6 Percentage of population with low fibre intake (<25g fibre daily)



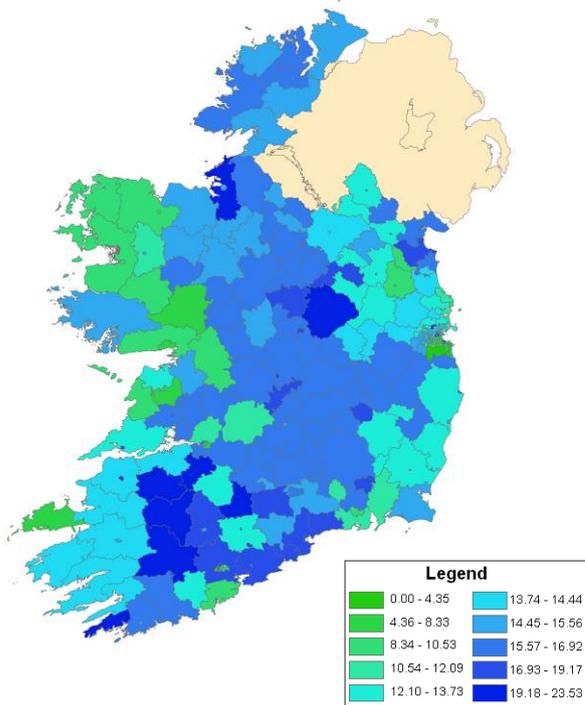
Map APP1.7 Percentage of population with high intake of red and processed meat (>300g/week)



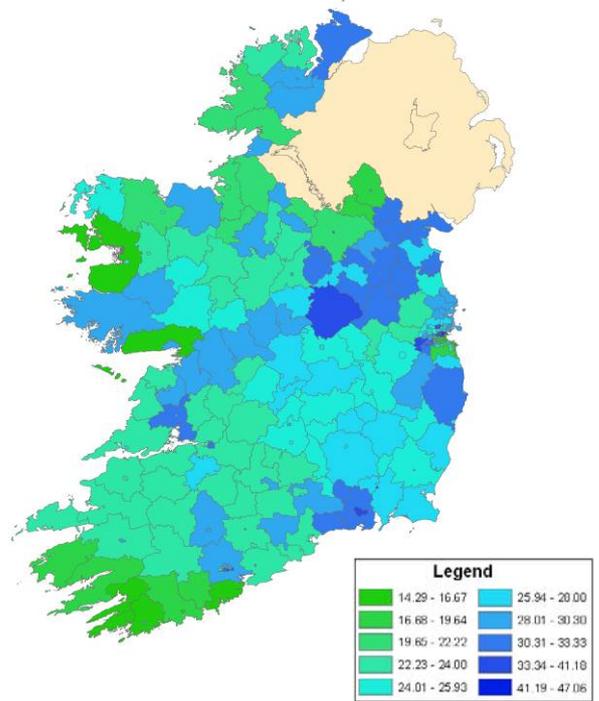
Map APP1.8 Percentage of population who have heavy alcohol consumption (≥14 units per week)



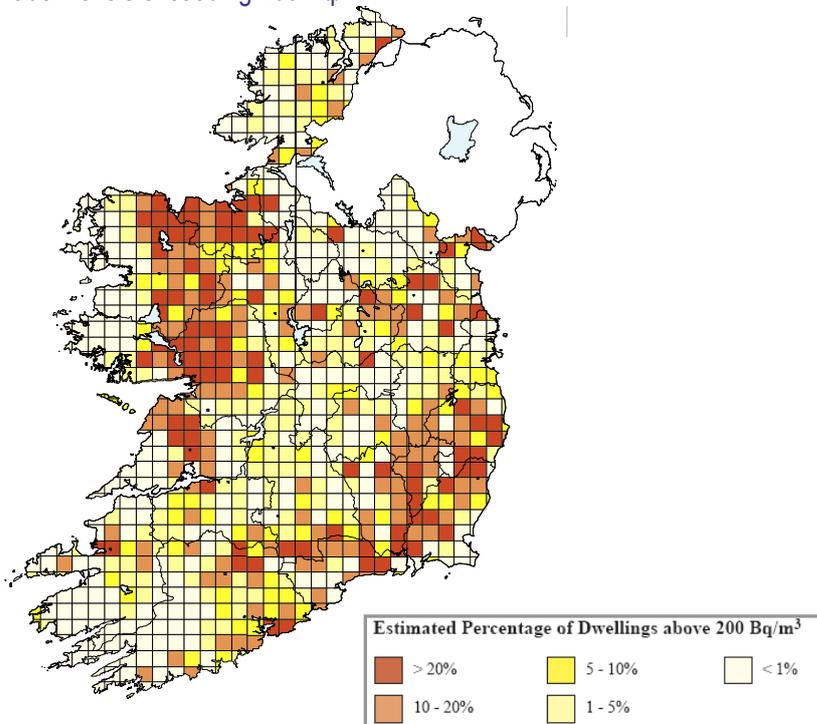
Map APP1.9 Percentage of population who are obese (body mass index >30 kg/m²)



Map APP1.10 Percentage of population who are current smokers (daily or occasional smokers)



Map APP1.11 Predicted percentage of houses with radon levels exceeding 200 Bq/m³



Source: Fennell et al, 2002

Appendix 2 ED characteristics and cancer incidence: summary tables

Tables APP2.1 and APP2.2 summarise, for males and females separately, the results of the modelling of the associations between ED characteristics and cancer incidence, by site of cancer. The modelling methods are described in section 2.2.3.

Table APP2.1 Summary relative risks, with 95% confidence intervals, by area characteristic and cancer site - males

	all ¹	non-melanoma skin	colorectal	lung	prostate	stomach	bladder	melanoma	head and neck	oesophagus
deprivation ²	1.12* (1.09,1.14)	0.80* (0.77,0.83)	1.06* (1.00,1.12)	1.72* (1.63,1.83)	0.85* (0.81,0.89)	1.28* (1.16,1.42)	1.09 (0.99,1.20)	0.66* (0.58,0.76)	1.78* (1.60,1.98)	1.22* (1.07,1.39)
population density ³	1.23* (1.20,1.25)	1.15* (1.12,1.19)	1.22* (1.16,1.28)	1.62* (1.53,1.71)		1.45* (1.32,1.58)	1.39* (1.28,1.52)	1.21* (1.06,1.39)	1.26* (1.11,1.42)	1.21* (1.09,1.35)
% unemployed ⁴								0.87 (0.72,1.05)		
% early school leavers ⁴			0.99 (0.93,1.06)	1.21* (1.12,1.30)		1.37* (1.20,1.56)		0.69* (0.57,0.83)		
% lower social class ⁴	1.05* (1.02,1.08)	0.86* (0.82,0.90)			0.88* (0.83,0.93)		1.13* (1.02,1.25)		1.35* (1.16,1.58)	
% overcrowded ⁴	1.05* (1.02,1.08)	0.82* (0.79,0.86)		1.34* (1.26,1.43)	0.91* (0.86,0.96)	1.11 (0.99,1.24)		0.87 (0.73,1.03)	1.16* (1.03,1.30)	
% local authority housing ⁴				1.26* (1.17,1.36)						
% with no car ⁴					0.90* (0.85,0.95)				1.41* (1.19,1.66)	
% aged 65+ living alone ⁴	1.15* (1.13,1.18)	1.10* (1.06,1.14)	1.15* (1.09,1.22)	1.23* (1.16,1.30)	1.14* (1.08,1.20)	1.11* (1.00,1.24)	1.12* (1.00,1.24)	1.16* (1.00,1.35)	1.23* (1.09,1.39)	1.28* (1.12,1.47)
% agricultural workers ⁴	0.79* (0.77,0.80)	0.78* (0.76,0.80)	0.79* (0.75,0.84)	0.52* (0.49,0.55)		0.63* (0.56,0.70)	0.64* (0.58,0.71)	0.85* (0.76,0.94)	0.77* (0.68,0.86)	0.78* (0.71,0.86)
% non-manual workers ⁴					1.21* (1.14,1.27)					

¹ all malignant cancers (excluding non-melanoma skin cancer); ² Relative risk of cancer in the most compared to the least deprived areas adjusted for population density; ³ Adjusted relative risks for areas with the highest density (>20 pa/ha) compared to areas with the lowest density (<1 pa/ha); ⁴ Adjusted relative risks for areas in the highest quartile compared to the lowest quartile; *p<0.05

Table APP2.2 Summary relative risks, with 95% confidence intervals, by geographical characteristic and cancer site - females

	all ¹	non-melanoma skin	breast	colorectal	lung	stomach	bladder	melanoma	head and neck	oesophagus	cervix uteri
deprivation ²	1.04* (1.02,1.06)	0.85* (0.82,0.88)	0.88* (0.84,0.91)	1.01 (0.95,1.07)	1.56* (1.45,1.68)	1.42* (1.24,1.61)	1.20* (1.03,1.39)	0.64* (0.57,0.71)	1.33* (1.11,1.58)	1.17* (1.00,1.37)	1.74* (1.53,1.99)
population density ³	1.17* (1.15,1.20)	1.33* (1.29,1.37)	1.17* (1.13,1.22)	1.06* (1.01,1.12)	1.84* (1.72,1.98)	1.49* (1.33,1.68)	1.40* (1.22,1.60)	1.15* (1.04,1.28)	1.25* (1.02,1.54)	1.23* (1.08,1.41)	1.19* (1.06,1.33)
% unemployed ⁴			0.96 (0.90,1.01)					0.75* (0.65,0.87)			
% early school leavers ⁴			0.89* (0.84,0.94)	0.86* (0.80,0.92)	1.13* (1.02,1.25)	1.28* (1.09,1.50)		0.77* (0.66,0.89)			
% lower social class ⁴	1.00 (0.97,1.03)	0.90* (0.86,0.94)					1.19* (1.01,1.40)		1.16 (0.90,1.50)		
% overcrowded ⁴	1.02 (0.99,1.05)	0.86* (0.82,0.90)	0.93* (0.88,0.98)		1.31* (1.20,1.43)	1.18* (1.02,1.37)		0.79* (0.69,0.90)	1.12 (0.91,1.37)		
% local authority housing ⁴					1.29* (1.17,1.43)						1.89* (1.65,2.17)
% with no car ⁴									1.31 (0.99,1.74)		
% aged 65+ living alone ⁴	1.14* (1.11,1.16)	1.11* (1.07,1.16)	1.10* (1.05,1.15)	1.29* (1.21,1.38)	1.18* (1.09,1.28)	1.23* (1.07,1.41)	1.16 (0.98,1.37)	1.12 (1.00,1.26)	1.01 (0.83,1.24)	1.27* (1.07,1.50)	
% agricultural workers ⁴	0.82* (0.80,0.84)	0.71* (0.68,0.74)	0.83* (0.79,0.87)	0.90* (0.85,0.96)	0.47* (0.43,0.51)	0.64* (0.55,0.73)	0.70* (0.59,0.82)	0.85* (0.74,0.97)	0.73* (0.57,0.92)	0.80* (0.69,0.94)	0.79* (0.68,0.91)

¹ all malignant cancers (excluding non-melanoma skin cancer); ² Relative risk of cancer in the most compared to the least deprived areas adjusted for population density; ³ Adjusted relative risks for areas with the highest density (>20 pa/ha) compared to areas with the lowest density (<1 pa/ha); ⁴ Adjusted relative risks for areas in the highest quartile compared to the lowest quartile; *p<0.05

Appendix 3 Summary statistics for the maps

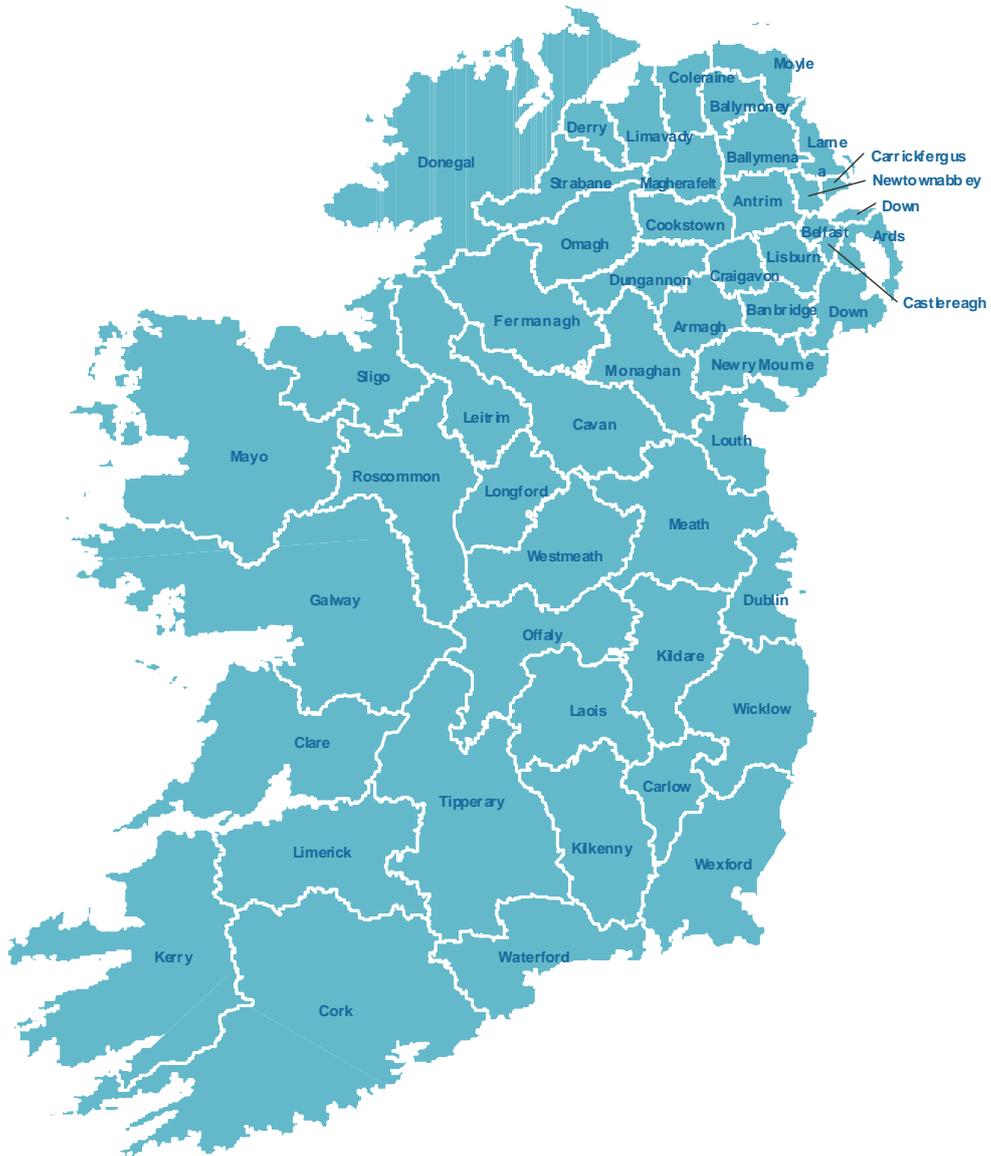
Table APP3.1 provides summary statistics for the maps for each cancer site, for males and female separately where relevant. The average number of cases per ED and the mean crude and smoothed RRs are shown, together with the minimum and maximum values, to give some idea of the range of risk estimates observed.

Table APP3.1 Summary statistics for each cancer site mapped: number of cases per ED, crude and smoothed RRs, with mean, minimum and maximum values

Cancer site	no. of cases per ED				crude RR				Smoothed RR			
	mean		(min-max)		mean ²		(min-max)		mean ²		(min-max)	
	females	males	females	males	females	males	females	males	females	males	females	males
all malignant cancers ¹	17.5	18.4	(0 - 358)	(0 - 351)	0.96	0.96	(0 - 5.76)	(0 - 3.42)	0.96	0.97	(0-1.35)	(0-1.52)
non-melanoma skin	6.5	7.2	(0 - 194)	(0 - 175)	0.88	0.94	(0 - 5.9)	(0 - 5.47)	0.90	0.94	(0-2.16)	(0-1.85)
breast	5.1	-	(0 - 113)	-	0.93	-	(0 - 6.79)	-	0.96	-	(0-1.28)	-
colorectal	2.2	2.9	(0 - 46)	(0 - 54)	0.99	0.94	(0 - 9.28)	(0 - 7.81)	0.98	0.97	(0-1.46)	(0-1.44)
lung	1.6	2.9	(0 - 37)	(0 - 46)	0.81	0.91	(0 - 11.2)	(0 - 10.73)	0.86	0.92	(0-2.49)	(0-2.73)
prostate	-	4.2	-	(0 - 80)	-	0.99	-	(0 - 6.8)	-	0.99	-	(0-1.61)
lymphoma	0.7	0.8	(0 - 15)	(0 - 17)	1.03	1.00	(0 - 36.82)	(0 - 15.17)	0.99 ³		(0-1.37)	
stomach	0.5	0.8	(0 - 13)	(0 - 11)	0.96	0.96	(0 - 30.16)	(0 - 19.7)	0.94	0.95	(0-2.25)	(0-1.79)
bladder	0.4	0.9	(0 - 10)	(0 - 19)	0.98	0.90	(0 - 29.18)	(0 - 11.39)	0.97	0.95	(0-1.29)	(0-1.4)
melanoma of the skin	0.7	0.4	(0 - 16)	(0 - 16)	0.97	0.87	(0 - 18.4)	(0 - 5.66)	0.95	0.95	(0-1.78)	(0-1.9)
leukaemia	0.4	0.6	(0 - 12)	(0 - 12)	1.04	1.02	(0 - 34.42)	(0 - 17.6)	1.01 ³		(0-1.14)	
head and neck	0.3	0.8	(0 - 9)	(0 - 16)	0.88	0.91	(0 - 28.22)	(0 - 17.69)	0.96	0.93	(0-1.24)	(0-2.8)
pancreas	0.5	0.5	(0 - 20)	(0 - 11)	1.00	1.04	(0 - 34.85)	(0 - 22.85)	1.01 ³		(0-1.14)	
ovary	1.0	-	(0 - 18)	-	1.00		(0 - 30.49)	(0 - 6.8)	1.01	-	(0-1.06)	-
brain and other CNS	0.4	0.5	(0 - 10)	(0 - 10)	0.96	1.00	(0 - 31.98)	(0 - 21.78)	1.00 ³		(0-1.04)	
kidney	0.3	0.5	(0 - 6)	(0 - 13)	0.94	0.95	(0 - 29.97)	(0 - 17.79)	0.98 ³		(0-1.15)	
oesophagus	0.3	0.5	(0 - 7)	(0 - 15)	1.00	0.99	(0 - 32.15)	(0 - 25.51)	0.97	0.98	(0-1.38)	(0-1.36)
corpus uteri	0.7	-	(0 - 12)	-	1.04	-	(0 - 31.97)	-	1.01	-	(0-1.18)	-
cervix uteri	0.5	-	(0 - 19)	-	0.88	-	(0 - 23.75)	-	0.96	-	(0-1.75)	-

¹ excludes non-melanoma skin cancer; ² mean relative risk (RR) across EDs, not weighted by population distribution (mean RR weighed by population is always 1.0); ³ smoothed RRs computed for males and females combined

Appendix 4 County and district council boundaries in Ireland



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