Environmental issue report | No 35

Mapping the impacts of recent natural disasters and technological accidents in Europe

European Environment Agency

Cover photos: Goppenstein, Switzerland, Feruary 1999 (Swiss Federal Institute for Snow and Avalanche Research SFL, Davos, Switzerland); Overflow of highly contaminated slurriesdue to rupture of the dam at Aznalcóllar (Spain), near Doñana National Park, 26/04/98 (Consejería de Medio Ambiente, Junta de andalucía); Forest fires in Portugal, summer 2003 (Miguel Galante/Direcção-Geral das Florestas, Portugal)
Cover design: Rolf Kuchling, EEA
Layout: Brandpunkt a/s and Lorena Marcaletti, EEA

ISBN: 92-9167-630-6

Environmental production:
This publication is printed according to the highest environmental standards.
Printed by Scanprint a/s:
— Environment Certificate: ISO 14001
— Quality Certificate: ISO 9001:2000
— EMAS registered; licence no. DK-S-000015
— Approved for printing with the Nordic Swan environmental label, licence no. 541 055
Paper:
— 100 % recycled and chlorine-free bleached paper
— The Nordic Swan Label

Printed in Denmark

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Acknowledgements

This report was prepared by the European Environment Agency and its European Topic Centre for Terrestrial Environment (ETC/TE). The lead author was Prof. David Saurí from Autonomous University of Barcelona, with contributions from Roger Milego, Aleix Canalís, Anna Ripoll and Stefan Kleeschulte (all members of the core team of ETC/TE).

EEA project managers were Adriana Gheorghe and Chris Steenmans. Tony Carritt did the English editing.

EEA and ETC/TE gratefully acknowledge the support received from:

Major Accident Hazards Bureau (MAHB), DG Joint Research Centre, European Commission: Contribution to the chapter on industrial accidents and comments on the draft report.

Natural and environmental disaster information exchange system (NEDIES) project, DG Joint Research Centre, European Commission: Contribution to the chapter on landslides and comments on the draft report.

Swiss Federal Institute for Snow and Avalanche Research (SLF), Davos: Main text, figures and illustrations for the chapter on avalanches.

UNEP GRID Geneva: Contribution and maps to the chapter on droughts.

Prof. Dr. Siegfried Demuth — German Federal Institute of Hydrology, Koblenz: Contribution to the chapter on droughts.

Ministry of Environment, Spatial Planning and Energy/Environmental Protection Agency of Slovenia (national focal point for EEA) and 'Anton Melik' Geographical Institute of Slovenia: Case study on landslides.

Ministry of Agriculture, Water and Environmental Protection, Romania (EEA national focal point) and National institute for research and environmental engineering, Romania: Case study on chemical spills.

Civil Protection Unit, Directorate General for Environment, European Commission: Comments on the draft report.

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Summary

This report brings together information about natural disasters and technological accidents that have occurred across Europe in recent years and their impacts on the environment and society. Much of this information is illustrated through maps, many created specially for this report, graphics and suggestive photographs. The most dramatic of these events are brought alive through case studies, based largely on local information, which detail their chronology and consequences. The report concentrates on the period 1998-2002 but includes preliminary information for 2003 wherever possible.

The natural disasters covered are floods, storms, forest fires, droughts, landslides, snow avalanches and earthquakes. Among technological accidents, oil spills, industrial accidents and mining accidents are considered.

In terms of geographical coverage, the focus of the report is on the 31 EEA member countries (the 15 EU Member States, the 13 acceding and candidate countries, Norway, Liechtenstein and Iceland) as well as Switzerland. However, the geographical scope was broadened when information about other European countries was available and relevant.

The report is far from being exhaustive and does not deal with biological hazards (e.g. epidemics), social hazards (terrorism, war) or certain types of technological risks such as nuclear accidents. Nor does it cover hazards related to chronic exposure to harmful substances or transport accidents other than those involving dangerous substances.

The report does not try to discern trends in extreme events themselves, for instance whether they are becoming more frequent. Its focus is on mapping the human, economic and environmental impacts of such events in Europe over the period. The overviews at the start of each chapter indicate the extent of these impacts for the major events.

Introduction

For the purposes of this report natural disasters are defined as events of natural origin that cause health, economic and environmental damage. Technological accidents are defined as negative events of human (mostly industrial) origin causing the same types of damage. Although health impacts may be relevant, most of the impacts dealt with in this report refer to human casualties and to economic and environmental damage.

Impacts on the environment and society

Between 1998 and 2002, natural disasters and technological accidents in Europe affected more than seven million people and caused at least 60 billion euro in insured losses (EM-DAT) (1). Total losses are bound to have been far higher since many will not have been insured.

This high cost suggests that individual and collective (i.e. policy) responses need to be improved. Recent initiatives by European authorities include the following:

- the EU water framework directive, which requires integrated assessment of water resources, including floods and droughts;
- the extension of the 'Seveso' directive on industrial accident hazards to cover mining activities;
- the harmonisation of certain building industry standards that are of particular relevance for regions prone to earthquakes;
- the tightening of EU and international rules on maritime safety;
- comprehensive research and development programmes in many European institutions.

Natural disasters can have significant environmental impacts which, depending on the event, may affect more than one country. Extreme storms, for instance, may be very damaging for forests and other natural habitats, as was the case in France, Germany and Switzerland in December 1999. Forest fires may destroy rich forest ecosystems and adversely affect rare plant and animal species. Landslides and snow avalanches often remove or damage the biotic stock of the areas located along their paths. Extreme events can cause a 'domino effect' of other, more indirect impacts, such as the mobilisation by floods of toxic substances in the soil that then infiltrate aquifers, the degradation of soils by forest fires, fires and explosions triggered by earthquakes, or a deterioration in water quality caused by drought.

But extreme natural events also perform important functions for the maintenance of natural ecosystems. Forest fires, for example, may create new habitats, thus revitalising forest biodiversity. Floods are essential for riparian forests and wetlands as well as for the recharge of aquifers and for the renewal of soil fertility, while avalanches can create the conditions for new plant species to grow. Even droughts can have positive functions by eliminating unwanted alien species that are less able to cope with lack of moisture than indigenous ones.

In certain cases, the environmental impacts of some preventive measures may be greater than the environmental impacts of the events themselves. Forest fire prevention, for instance, may lead to a build-up of biomass that increases the magnitude of future fires. Extensive flood control works alter the state and dynamics of river ecosystems with

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(1) The EM-DAT international disaster database (http://www.cred.be/emdat) is a database on the occurrence and immediate effects of all disasters in the world, from 1900 to the present. It is maintained by the US office of Foreign Disaster Assistance (OFDA) and the WHO Collaborating Centre for Research on the Epidemiology of Disasters (CRED) and is located at the University of Louvain (Belgium). The database is compiled from various sources, including United Nations agencies, non-governmental organisations, insurance companies, research institutes and press agencies. An event is included in EM-DAT if 10 or more people were killed; or 100 or more people were affected, injured or left homeless; or it was a significant disaster (e.g. 'second worst'); or it caused significant damage; or it caused the declaration of a state of emergency or/and appeal for international assistance; or it was a disaster entered at the country level without data, because it has affected several countries/regions. The date and location of each event are provided, as well as the numbers of people killed and injured where such information is available. The EM-DAT database will improve over the next year. In particular, plans are underway to improve the European region data.

deleterious effects on species and communities.

Compared with disasters of natural origin, most technological accidents do not tend to cause as many deaths or as much economic damage (Dauphiné, 2001). However, their catastrophic potential, especially in environmental terms, can be much greater than that of natural events. For example, marine oil spills and mining accidents resulting in the discharge of hazardous waste into water bodies can damage valuable ecosystems, as with the wrecks of the oil tankers *Erika* (1999) and *Prestige* (2002) and the chemical spills at Doñana (Spain) in 1998 and Baia Mare (Romania) in 2000.

Many European regions are affected by multiple and repeated hazards, producing greater impacts than the simple sum of the individual events.

In some industrial accidents, however, the main impacts are extensive material damage and human casualties. Explosions at a fireworks warehouse at Enschede (the Netherlands) in 2000 and at a fertiliser factory at Toulouse (France) in 2001 caused several dozen deaths and destroyed urban neighbourhoods in the vicinity of the plants.

Like natural disasters, technological accidents can sometimes have an important trans-boundary dimension, as in the cases of the *Prestige* and Baia Mare incidents.

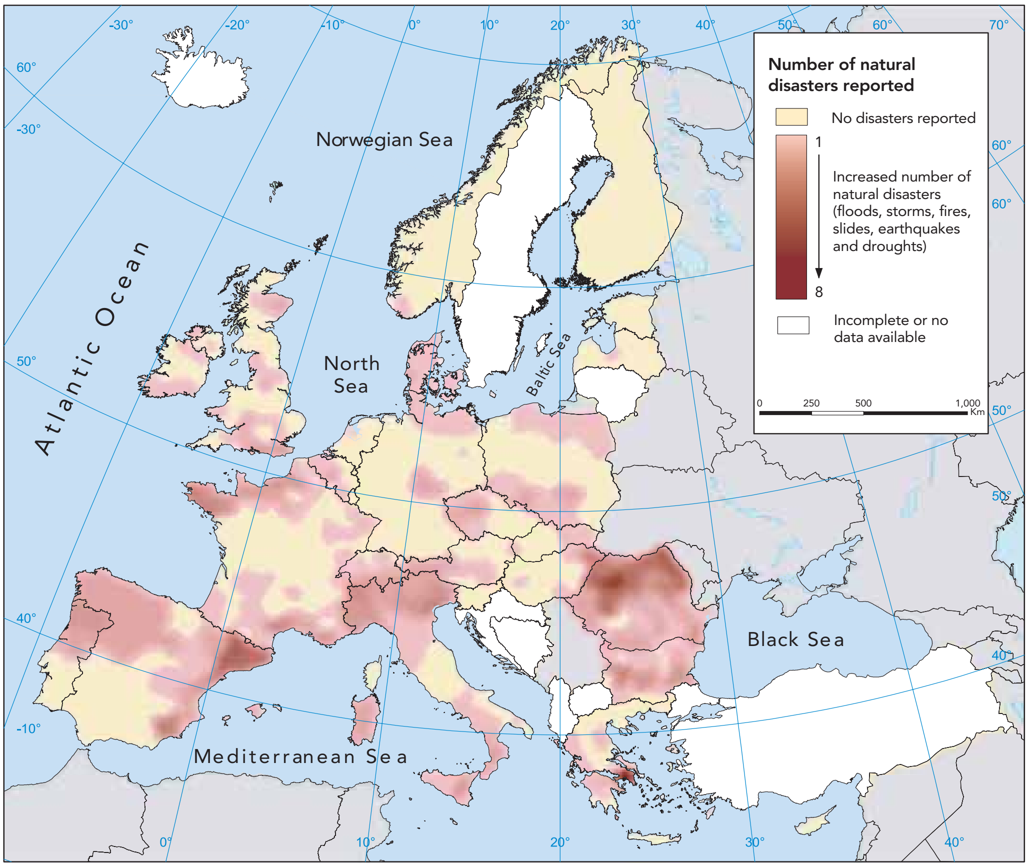
Occurrence

Europe's diverse geophysical and climatic characteristics make it susceptible to a wide range of extreme natural events. Thus, the large river systems of western, central and eastern Europe, as well as the smaller streams of the Mediterranean, make these areas vulnerable to flooding. Similarly, southern Europe is prone to drought, the Mediterranean and eastern Europe to forest fires, western Europe and the British Isles to storms, mountain areas such as the Alps, the Pyrenees and the Carpathians to avalanches and specific areas such as the central and eastern Mediterranean to earthquakes and volcanic eruptions.

As Map 1 shows, many regions of Europe can be affected by multiple and repeated natural disasters, producing greater impacts than the simple sum of individual events. The extremes of flood and drought in the Mediterranean countries are an example of this.

Map 1 **Occurrence of major natural disasters (1998–2002)**

Source: EEA-ETC/TE, 2003 (based on EM-DAT).



Sites of major technological accidents (1998–2002) Map 2

Source: EEA-ETC/TE, 2003 (based on EM-DAT / International Tanker Owners Pollution Federation Limited (ITOPF)).

Regarding technological accidents, the three types addressed in this report — oil spills, industrial accidents and mining accidents — have been chosen because of their potential to cause considerable environmental damage, because they occur fairly frequently and because policy intervention is needed to remedy their damage and prevent their recurrence.

As Map 2 shows, such accidents have occurred all over Europe in the recent past. Of the three types, the oil spills probably had the greatest environmental impact.

References

Ayala Carcedo, F.J. and Olcina Cantos, J. (ed.), 2003: *Riesgos Naturales*. Barcelona: Ariel.

Cutter, S.L., 1993: *Living with Risk*. London: Edward Arnold. (Chapter 1).

Dauphiné, A., 2001: *Risques et catastrophes*. Observer-Spatialiser-Comprendre-Gérer. Paris: Armand Colin (Chapters 1–3).

EEA, 2003: *Europe's environment: the third assessment report* (Environmental assessment report No 10). Copenhagen: European Environment Agency.

McGuire, B., Mason, I., and Kilburn, C., 2002: *Natural hazards and global environmental change*. London: Arnold. (Chapter 1).

Mitchell, J.K., 1996: 'Improving community responses to industrial disasters', in Mitchell, J.K. (ed.) *The long road to recovery. Community responses to industrial disaster.* Tokyo: United Nations University Press. (pp. 10–40).

Perrow, C., 1999: *Normal accidents. Living with high risk technologies*. Princeton: Princeton University Press (2nd edition).

Reice, S.R., 2001: *The silver lining. The benefits of natural disasters*. Princeton and London: Princeton University Press (Chapter 1).

Smith, K., 1993: *Environmental hazards. Assessing risk and reducing disaster.* London: Routledge. (Chapters 1–2).

Useful links

Title: GRID — Geneva Major Activities — Early warning — PreView
URL: http://www.grid.unep.ch/activities/earlywarning/preview/ims/index.php

Title: UNEP APELL
URL: http://www.uneptie.org/pc/apell/home.html

Title: UNEP — Division of environmental policy implementation
URL: http://www.unep.org/DEPI/disastermanagement1.asp

Title: CEOSDIS — Committee on Earth observation satellites disaster management support group
URL: http://disaster.ceos.org

Title: EM-DAT: The OFDA/CRED international disaster database
URL: http://www.cred.be/emdat

Title: UNEP: The GEO-3 Data Compendium
URL: http://geocompendium.grid.unep.ch/data_sets/disasters/nat_disaster_ds.htm

Title: Natural and environmental disaster information exchange system (NEDIES)
URL: http://nedies.jrc.it/default.asp

Title: MITCH, Mitigation of climate induced natural hazards
URL: http://www.mitch-ec.net

Title: JRC: Natural hazards project
URL: http://natural-hazards.jrc.it

Title: Natural Hazards.org: Education and research for a safer planet
URL: http://www.naturalhazards.org

Title: NASA: Natural disaster reference database
URL: http://ndrd.gsfc.nasa.gov

Floods

Date of the event (1998–2002)	Location	Impact
May 1998	Campania (Italy)	Torrential rains, state of emergency declared, about 150 people killed and more than 3 000 affected.
May 1998	Zonguldak, Karabul, Bartin (Turkey)	70 % of Bartin under water, 16 people killed, very high economic losses of around 1.2 bn euro, including about 30 000 chickens and 150 cattle.
June 1998	Bacau, Vaslui, Salaj, Mures, Neamt, Cluj, Alba, Sibiu, Hunedoara (Romania)	Some 23 people killed and more than 10 000 affected as over 1 000 km^2 flooded, including about 160 000 hectares of agricultural land. More than 500 km of roads, 270 bridges, more than 1 800 houses destroyed. High economic losses of about 150 m euro.
July 1998	Sabinov, Presov (Slovakia)	82 villages hit, about 50 people killed and over 10 000 affected as more than 2 000 houses flooded. Over 5 000 animals killed.
May 1999	Bavaria (Germany)	More than 120 km^2 flooded as a dam breaks, three people killed and hundreds evacuated.
June 1999	Romania	Some 19 people killed, more than 1 500 houses and about 23 000 hectares of agricultural land destroyed, more than 300 km of roads damaged.
November 1999	Aude, Tarn, Herault, Pyrenées-Orientales (France)	State of emergency declared in more than 300 communes, about 35 people killed, 1 000 evacuated, 1 000 hectares of vineyards destroyed.
February 2000	Hungary	About 3 250 km^2 flooded.
April 2000	Boka, Borsod-Abauj-Zemplen, Szabolcs-Szatmar-Bereg (Hungary)	About 2 500 km^2 flooded, more than 20 000 people evacuated.
April 2000	Alba, Arad, Bihor, Bistrita, Botosani, Brasov, Caras-Severin, Cluj, Harghita, Hunedoara, Maramures, Mures, Olt, Satu-Mare, Salaj, Timis (Romania)	Nine people killed as about 1 000 km^2 flooded, around 80 000 hectares of agricultural land damaged, about 9 000 houses flooded, hundreds of bridges destroyed.
October 2000	Piedmont, Val d'Aoste, Liguria (Italy)	Twenty-nine people dead, more than 40 000 affected, about 6 000 homeless. High economic losses of more than 430 m euro.
October 2000	Kent, Sussex, Hampshire (UK)	Hundreds of families evacuated, very high economic losses (about 6 bn euro).
June 2001	Central + south Transylvania (Romania)	Seven people killed and about 10 000 affected as around 500 km^2 flooded, more than 3 000 houses damaged.
August 2002	Austria, Belgium, Bulgaria, Czech Republic, France, Germany, Italy, Romania, Switzerland, Slovakia, United Kingdom	Major flood event of the five-year period. More than 600 000 people affected and about 80 dead in 11 countries affected. Huge economic losses (at least 15 bn euro), road and rail transport severely disrupted, some 100 000 hectares of agricultural land flooded, big cities flooded (e.g. Prague, Dresden), damage to cultural heritage, many landslides triggered.
September 2002	Lezha, Shkoder, Fier, Gjirokaster (Albania)	About 260 km^2 flooded, about 16 000 houses badly damaged, more than 60 000 people affected, sanitation and water supply problems. State of emergency declared in six prefectures.

Source: EM-DAT, 2003.

Floods are natural phenomena and therefore expected to occur. A distinction needs to be made between normal (annual) flooding events, usually producing very little or no damage, and exceptional events that can have severe impacts. Floods can also have important beneficial effects for river ecosystems, groundwater recharge and soil fertility.

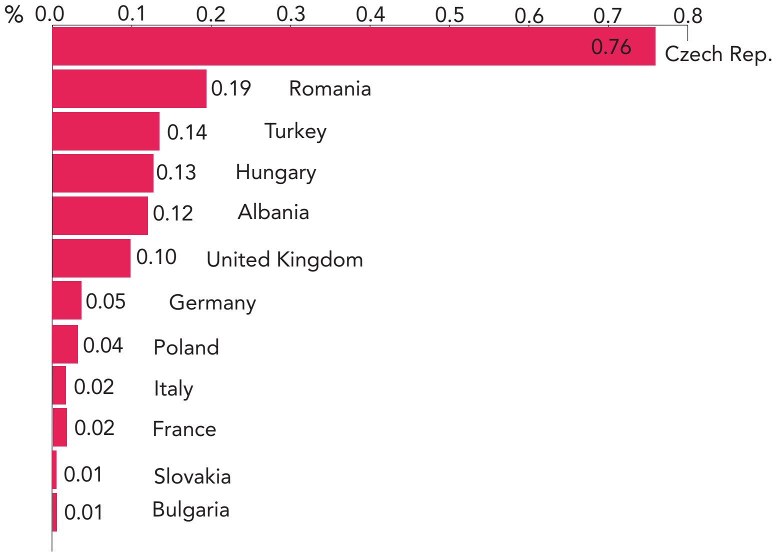
Over the past five years floods affected an estimated land area of one million square kilometres.

According to EM-DAT, floods comprised 43 % of all disaster events for the period 1998–2002. During this period, Europe suffered about 100 major damaging floods, causing some 700 fatalities, the displacement of about half a million people and at least 25 billion euro in insured economic losses. These covered an estimated one million square kilometres (though this figure includes areas that were flooded more than once (see Map 3) so the actual total may be less). The number of people affected by flooding was around 1.5 % of the European population.

Figure 1

Annual average cost of flood damage as percent of gross domestic product (GDP) for the most affected European countries, 1998–2002

Sources: EM-DAT, 2003
United Nations
Department of Economic
and Social Affairs.



Note: These figures are definitely underestimated since economic losses were reported for only 34 % of floods over the period.

Exact figures for economic losses are always difficult to determine since data is available for only a fraction of total events. The impact of floods on the economy varies considerably from country to country but can be very heavy for some, especially those with economies in transition where many priorities have to be addressed in a relatively short time. As Figure 1 indicates, of the countries most affected by floods between 1998 and 2002, eight are in central and eastern Europe. As almost all these countries are acceding or candidate countries, flooding will be a greater challenge for an enlarged EU.

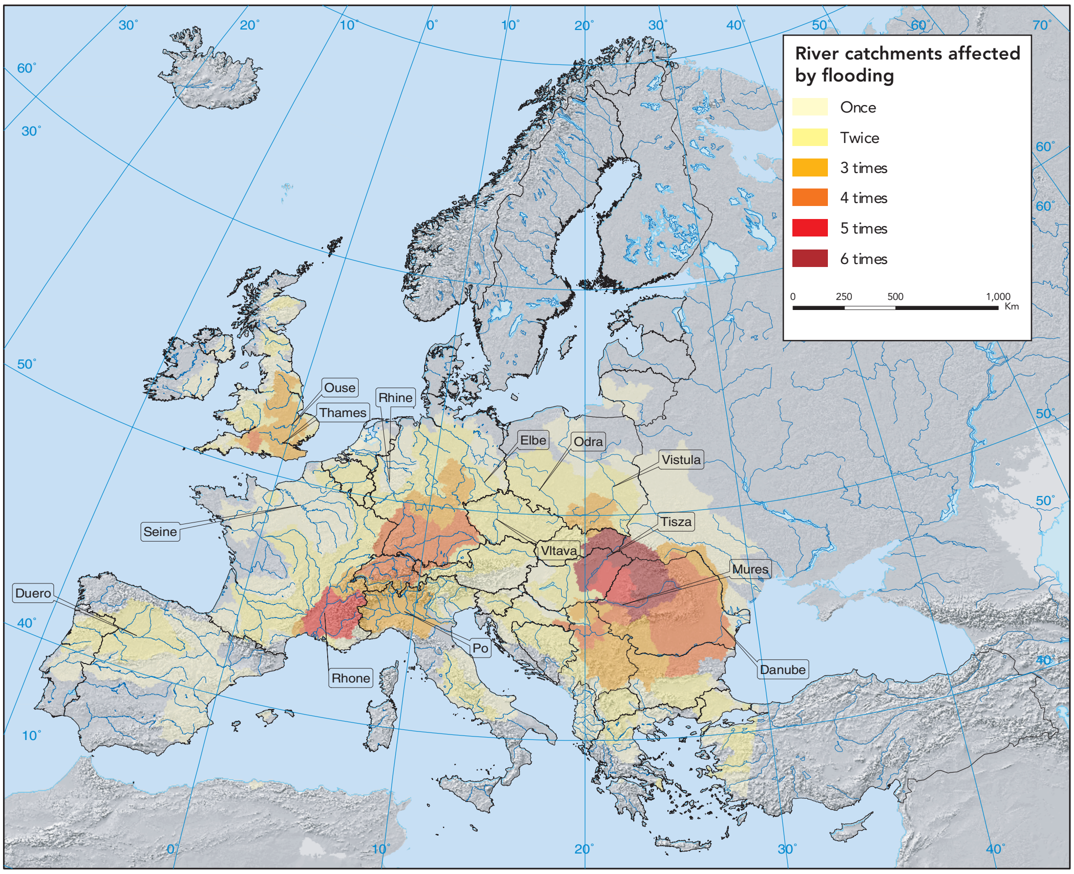
From the damaging floods that occurred in Europe over the 1998–2002 period it is evident that several areas tend to be flooded several times over relatively short periods of time. As Map 3 shows, north-west Romania, south-eastern France, central and southern Germany, northern Italy, and the east of England experienced the highest concentration of repeated flooding.

As the table at the beginning of this chapter summarising the major floods of the past five years underlines, exceptional flooding carries very significant impacts. For example, the floods in southern France in September 2002 affected more than 300 municipalities (80 %) in the department of Gard and caused damage estimated in the region of 1.2 billion euro. But flooding has benefits too. In eastern Spain, for instance, large floods are very important for the recharge of groundwater aquifers used for agriculture and for tourism, and for the maintenance of coastal wetlands.

The Elbe flood of 2002 did not reach Hamburg as feared because the large and relatively undeveloped flood plain in the lower course of the river absorbed a substantial amount of the excess flows.

The downstream and transboundary impacts of floods can be very significant, although they depend on prevailing land uses in the different parts of the river basins. For example the Elbe flood of 2002 did not reach Hamburg as feared because the large and relatively unoccupied flood plain in the lower course of the river absorbed a substantial amount of the excess flows. In some places, such as in Mediterranean areas , flooding (leading to soil erosion) can combine with forest fires and soil degradation to cause desertification. It is estimated that more than one third of Spain (especially the south and the east) is at risk in this respect (*El País*, 19 May 2003).

Recurrence of flood events in Europe between 1998–2002 Map 3



Source: ETC/TE, 2003 (based on NASA-supported Dartmouth Flood Observatory / Digital Elevation Model (GISCO) / Rivers (GISCO) / Watersheds 1M (JRC-IES) / Administrative boundaries (GISCO)).

North-west Romania, south-eastern France, central and southern Germany, northern Italy, and the east of England experienced the highest concentration of repeated flooding between 1998 and 2002.

Note: In producing this map, satellite images of the flooded areas were examined and used as a basis for mapping the major river catchments affected by flooding during the period 1998–2002. Therefore the areas indicated as flooded do not exactly coincide with the actual flooded area.

Examples of the environmental impacts of floods, 1998–2002

The environmental impact of floods occurring in large rivers includes the clogging up of water treatment plants (potentially leading to the release of large quantities of contaminants), damage to vegetation, in some cases due to the duration of residence of water in the soil, and the mobilisation of contaminants present in the soil. For example, there was great concern that the summer 2002 floods would mobilise hazardous substances contaminating the area around the Bitterfeld chemical complex in the German region of Sachsen-Anhalt. In the event this did not happen.

Flash floods can cause widespread destruction, although usually in relatively small areas and environmental damage, especially soil erosion, both on their own and in association with other natural events such as landslides. Fairly common in the Mediterranean and mountain areas, flash floods are a particular danger to people since, as their name suggests, they happen suddenly and with little warning. Floods in southern France in September 2002 killed 29 people (*Le Monde*, 12 September 2002).

Diffuse flooding can also have environmental impacts, facilitating for instance the infiltration of polluted run-off into the local aquifers. In October 2002, the Llobregat delta near the city of Barcelona — an area of significant urban, industrial and infrastructure growth — suffered a major flood of its drainage system during an episode of heavy rainfall.

Flooding caused by storms mainly affects coastal areas and, by erosion, related ecosystems. It may coincide with high waters in river estuaries as was the case with the floods in north-east England in the autumn of 2000.

Urban land expanded by 20 % in Europe during the period 1980–2000 while population increased by 6 %.

Land use changes and specifically urbanisation and infrastructure development are probably the main reason that flood damage is increasing. Urban land expanded by 20 % in Europe during the period 1980–2000 while population increased by 6 % (EEA, 2002). In part, this is because the demand for housing tends to be located away from compact urban centres and takes the form of single or semi-detached homes, requiring more land development. In other cases, for instance in the United Kingdom, the improvement in water quality has made riverside locations attractive for residential development once again and therefore more exposed to the risk of damage. If unregulated or carried out without heeding potential dangers, urban growth aggravates the flood risk since it may be located in flood-prone land, may alter natural patterns of drainage and may increase the circulation of overland flow.

The flooding episode of summer 2002 has been selected as the case study for this chapter to illustrate in detail some of the main arguments developed. It demonstrates that floods can have enormous impacts, often with an important transboundary component (three countries seriously affected). Although natural disasters can often lead to technological accidents that aggravate the impacts (e.g. the mobilisation of contaminants by flood waters), this was fortunately largely avoided in this case.

Flooding in central Europe, August 2002: Austria, the Czech Republic and Germany

In August 2002, severe flooding gripped central Europe for a period of almost three weeks. It surpassed all historical records. It was attributed to the same cause as other great flood events in recent years: the ground was saturated after long and continuous precipitation, so that subsequent intensive rainfall resulted in a flood. The flood mainly affected part of Austria, the Czech Republic and Germany. Smaller floods were also reported in Hungary and Slovakia. In all, around 4.2 million people were affected. Losses far exceeded those of the Odra/Oder flood in 1997. Whereas the Odra/Oder flood hit mainly rural areas, this time many cities, including major ones such as Prague and Dresden, were partly submerged (see table below).

	Odra Flood 1997	Flood August 2002
Countries affected	Czech Republic, Germany, Poland and Slovakia	Austria, Czech Republic, Germany and Slovakia
Casualties	100	112
People evacuated	300 000	400 000
Economic losses	EUR 5.0 billion	EUR 14.4 billion
Insured losses	EUR 0.8 billion	EUR 3.4 billion

Source: Yörn Tatge/Converium.

Areas affected by 2002 flooding

Source: EEA-ETC/TE, 2003.

Exceptionally heavy rainfall from storms that crossed central Europe in early August was focused in two areas: near the Czech/German border in the Ore Mountains, and in south Bohemia and northern Austria. One flood wave progressed down the River Danube through Austria, Slovakia and Hungary, causing minor damage to the region. A much more severe flood wave progressed down the Vltava River and its tributaries through Prague, the Czech capital, and subsequently down the Labe/Elbe River through north Bohemia. It then crossed the Czech Republic border into Germany. Peak discharges in many rivers exceeded 100-year flood levels, and in some rivers even 1000-year levels. For example, on 14 August 2002 the level of the River Vltava in Prague reached 785 centimetres (at a flow rate of 5 300 m^3 per second) — more than 12 times the average water level of 66 centimetres. According to the records on historical floods kept in Prague since 1827, the water level was higher than during the 1890 flood, when the 14th century Charles Bridge, one of the city's great landmarks, was partially damaged. On 17 August, in Dresden, the River Elbe level peaked at a record height of 940 centimetres, compared with its usual level of 186 centimetres, superseding the previous record set in 1845.

In the Czech Republic, a state of emergency was declared in five out of the nine regions hit by the flooding, including Prague. In Austria and Germany, large areas were declared disaster areas and granted emergency support.

In Prague, high stone walls bordering much of the river protect against flooding, but the low lying parts of the Mala Strana, the Old Town, and Karlin have no significant defences. The combined effects of surface water and underground seepage flooded the Metro, Prague's primary public transit system. Many museums, archives and libraries were inundated, as were municipal parks were flooded, including Stromovka and Troja. More than 400 animals had to be rescued from the zoological garden. Luckily the Charles Bridge escaped unscathed.

In the German city of Dresden, about 200 km from Prague, the River Weisseritz (a tributary of the Elbe) initially broke its banks on 12 August. Subsequent flooding submerged the main railway station and parts of the historic city centre. Fortunately, flood warnings allowed priceless works of art to be rescued from the lower floors of the Zwinger Palace.

Besides Prague and Dresden, the floodwaters of the Vltava and the Labe/Elbe caused extensive damage in more than 1 000 municipalities. On the River Danube, Passau in Germany and Salzburg, Linz and Steyr in Austria were reportedly the worst hit cities. Minor flooding was seen in Vienna and further downstream in Slovakia and Hungary.

The environmental impact of the flood is still being studied since the long-term impact on large areas extending far beyond the riverbanks, including the deposition of hazardous substances on the soil and in ecosystems, requires lengthy examination. Among the more direct impacts was serious damage to the parks and greenery in the vicinity of the Vltava and Elbe. A temporary negative impact on water quality was reported, caused mainly by the stoppage of waste water treatment plants that were put out of operation during and after the flood (more than 120 plants in the Czech Republic alone). Fortunately, there was little serious harm in designated conservation areas.

Most losses stem from commercial rather than residential properties. In Germany alone, the flood affected more than 12 000 small businesses. Losses from interruption to business have been estimated at more than 750 million. Large industrial facilities were generally less badly affected as these tend to be better protected against flooding. Also, these industrial sites became the focus of emergency measures due to their potential to cause pollution. Nevertheless, several instances of water and air pollution from industrial sites, including chemical plants such as Spolana Neratovice in the Czech Republic, were reported as a result of the flood. A chemical plant near Prague started leaking, spewing potentially deadly chlorine gas into the air. Also, the industrial area near Bitterfeld in Germany was partly submerged; its chemical and industrial facilities house dangerous substances that could have been released.

Prague

Source and copyright: Heather Faulkner, *The Prague Post.*

Dresden

Source and copyright: Feuerwehr Dresden.

References

Brown, J.D. and Damery, S.L., 2002: 'Managing flood risk in the UK: towards an integration of social and technical perspectives'. *Transactions of the Institute of British Geographers*, NS, 27, pp. 412–426.

Colombo, A.G., Hervás, J. and Vetere Arellano, A.L. (ed.), 2002a: *NEDIES Project — Guidelines on flash flood prevention and mitigation.* Report EUR 20386 EN. Luxembourg: Office of Official Publications of the European Community.

Colombo, A.G., Hervás, J. and Vetere Arellano, A.L. (ed.), 2002b: *NEDIES Project — Lessons learnt from flood disasters.* Report EUR 20261 EN. Luxembourg: Office of Official Publications of the European Community.

EEA, 2001: *Sustainable water use in Europe. Part 3: Extreme hydrological events. Floods and droughts* (Environmental issue report No 21). Copenhagen: European Environment Agency.

EEA, 2002: *Environmental signals 2002. Benchmarking the millennium* (Environmental assessment report No 9). Copenhagen: European Environment Agency.

EEA, 2004 (not published yet): *Air pollution and climate change policies in Europe: Exploring linkages and the added value of an integrated approach* (Technical report No 100). Copehangen: European Environment Agency.

Environment Agency (United Kingdom), 2001: *Lessons learnt autumn 2000 floods.* London: Environment Agency.

European Commission, 2000: Water Framework Directive (2000/60/EC). Brussels.

ICPR, 1995: *Constat et stratégie pour le plan d'action contre les inondations.* Strasbourg: Commission Internationale pour la protection du Rhin.

IPCC, 2001: *Climate Change 2001.* Cambridge: Cambridge University Press.

Gruntfest, E. and Montz, B.E., 2002: 'Flash flood mitigation: recommendations for research and applications', *Environmental hazards*, 4, pp. 15–22.

Useful links

Title: Dartmouth Flood Observatory
URL: http://www.dartmouth.edu/%7Efloods

Storms

Name of event	Date of the event (1998–2002)	Location	Impact
Cilly, Désirée and Fanny	January 1998	Britanny, western France, South Wales & Midlands (UK). Germany, Spain, Belgium, the Netherlands, Switzerland, Portugal, Austria and Poland also touched	About 15 people killed and more than 3 500 affected as violent winds damage over 1 200 homes. High economic losses of more than 500 m euro.
—	February 1999	Hungary	Forty people dead in snowstorm affecting about 250 000 hectares. 200 villages cut off.
Anatol	Early December 1999	Germany, southern Denmark, southern Sweden, Poland, Estonia, Latvia, Lithuania	Around 17 people killed, more than 500 m euros in economic losses. Power cut to about 160 000 homes, considerable damage to buildings and forests.
Lothar, Martin	Late December 1999	France, Switzerland, Germany, Denmark, Sweden, Poland, Lithuania, Austria and Spain	Almost four million people affected and 125 killed. Huge economic impact (insured losses about 6.7 bn euro). Damage to houses, infrastructure (electricity grid, transportation, communications lines), forests (millions of m^3 of wind-thrown timber, mainly in France, Switzerland and Germany). Environmental impacts, mainly within forest ecosystems.
Jeanett	October 2002	Austria, Belgium, Denmark, France, Germany, the Netherlands, Poland, Sweden, UK	More than 30 people dead and over 60 000 affected. Huge economic costs (about 1.5 bn of insured losses), thousands of trees uprooted, and many power lines, roads and railways damaged.

Source: EM-DAT, 2003.

Storms are among the most costly types of disasters, not least because of the destructive force of the high winds unleashed. Until the summer 2002 floods in central Europe, windstorm *Daria* in January 1990 and then storms *Lothar* and *Martin* in late December 1999 held the record for Europe's most expensive disasters in terms of insured losses, at nearly six billion euro and around 6.7 billion euro respectively. The three storms killed around 220 people in total.

Major storms occur most frequently in autumn and winter and can happen in rapid succession. *Daria* was followed the next month by storm *Vivian*, which caused 64 deaths and around US$ 3.9 billion in insured losses, while *Lothar* and *Martin* took place within the space of just three days.

As the table above makes clear, storms in Europe over the 1998–2002 period took a heavy toll in human casualties, environmental impacts — particularly in forests — and economic losses. The period's major episode was a succession of three storms in December 1999: *Lothar* and *Martin*, the subjects of this chapter's case study, preceded by *Anatol*. Taken together, these events were unprecedented in Europe in their intensity, the size of the geographical area affected and the level of economic and environmental losses. During *Lothar*, wind gusts of up to 180 km/h were recorded at Paris's Orly airport (EEA, 2003).

Storm frequency between 1998 and 2002 was particularly significant in western Europe although not exceptional. Storm damage on the scale caused by *Lothar* has a return period of 10 years on average, while storms causing up to one billion euro in damage are to be expected every two to three years (Swiss Re, 2000). In October 2002, storm *Jeanett* caused damage estimated at two billion euro (Munich Re, 2002).

Most storms over the period occurred around the mid-latitudes of Europe. As map 4 shows, some major storms followed similar tracks, meaning that certain areas were hit more than once. Tornadoes can also occur in Europe, although usually in the form of very small and very localised events (Baxter *et al.*, 2002).

France's timber losses in the storms of late December 1999 were more than three times its annual harvest.

Storms, together with other natural phenomena such as fires, play a big role in forest dynamics. They cause major disruption to temperate thick forests such as those affected by *Lothar* and *Martin*. Storm effects influence the structure of vegetation, the longevity of trees and the balance between species. Forest stocks are particularly vulnerable to storms. As Figure 2 shows, timber losses in France from the two storms at the end of December 1999 represented amounted to more than three times the country's annual harvest, and those in Switzerland to just under three times. (Swiss Re, 2000). According to some studies, conifer species appear to be more vulnerable to storm damage than deciduous species. Trees' height is also a factor in storm damage, with taller trees more vulnerable. Moreover, it has also been shown that some pests, such as bark beetles, have increased since the December 1999 storms. This may result in greater mortality rates for some spruce and pine species (BFH, 2002).

Map 4 shows the transboundary impact of storms in Europe over the period 1998–2002 and the diversity of areas affected (densely populated areas, large forest areas and agricultural land).

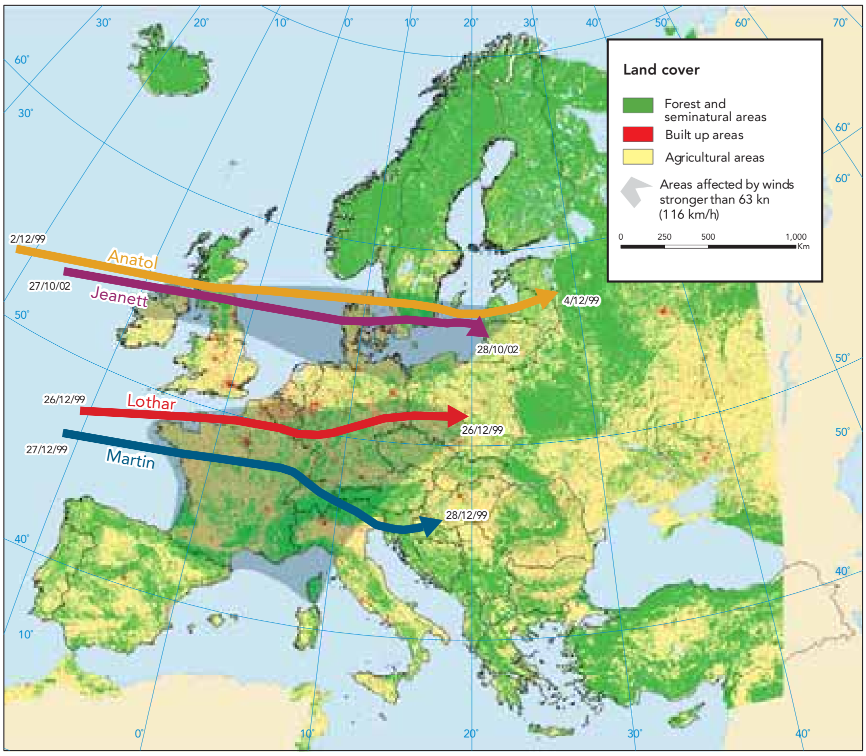
Figure 2 **Wind thrown timber from storms *Lothar* and *Martin*, December 1999, compared with annual harvest**

Source: UNECE, 2000. http:// www.unece.org/ trade/timber.

Country	Wind thrown timber (million m^3)	Annual harvest (million m^3)	Wind thrown timber as % of harvest
France	139.6	42.9	325
Switzerland	12	4.2	288
Denmark	3.5	2.2	159
Germany	30	39	77
Sweden	5	58.1	9
Poland	2	23.3	9
Lithuania	0.4	4.9	8
Austria	0.4	14	3
Total estimated	193	380.8	51

Map 4 **Course of major storms in 1998–2002**

Source: EEA-ETC/TE, 2003 (based on Deutscher Wetterdienst (German weather service) (2000), cited by Münchener Rück (Munich Re Group) in 'Winter storms in Europe' / Institut für Geophysik und Meteorologie der Universität zu Köln (Institute for Geophysics and Meteorology at Cologne University) (Germany) / Corine Land Cover 90 (EEA) / PELCOM database).



The following case study highlights the environmental consequences of the two storms in late December 1999, particularly their effects on the biotic systems in forests and other semi-natural environments.

Storm damage such as that caused by *Lothar* in 1999 has a return period of 10 years on average.

Storms *Lothar* and *Martin*, December 1999

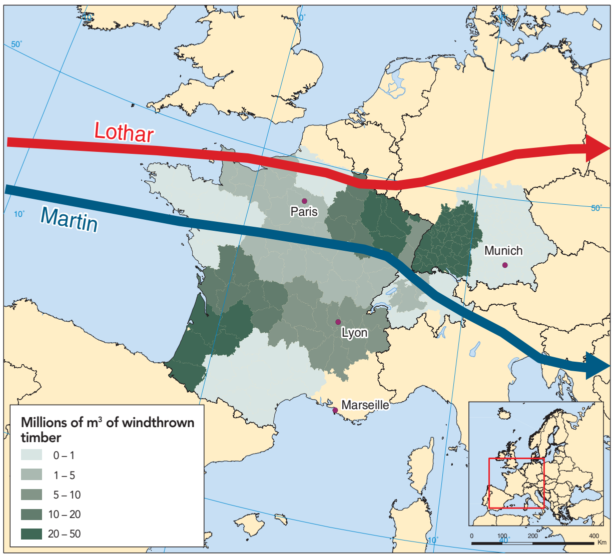
Between 26 and 28 December 1999, two extra-tropical cyclones (RSM, 2000), *Lothar* and *Martin,* swept across an area from northwestern France to Germany, and across southern France and Switzerland respectively (see map). Wind gusts reached speeds of more than 180 km/h in the first and 160 km/h in the second. The storms caused huge devastation, claiming 125 lives and damaging houses, infrastructure such as electricity grids and transportation and communications lines. At the time they were the most costly natural catastrophe ever to hit Europe, with total insured losses of 6.7 billion euros (CRED, Swiss Re.), many of them in the industrial and public sectors.

The storms struck large expanses of forests, with significant economic and ecological consequences. In terms of tree loss France was the country most affected, with about 140 million m^3 of wind thrown timber, equivalent to more than three times its annual harvest and around 7 % of the estimated global timber stock of two billion m^3. More than 40 % of the tree loss was concentrated in the Lorraine and Aquitaine regions. The German state of Baden-Württemberg was also particularly hard hit, with wind thrown timber also around three times its annual harvest (see map).

Based on research into previous similar events, French experts estimate the ecological consequences of the two storms to be as follows:

- The biggest impact is not the direct effects on fauna mortality but the change in forest structure. New clearings appear and there is a general rejuvenation of the forest.
- The creation of clearings favours crickets, day butterflies and certain Coleopters, which are often the food base for other species (insectivore birds, reptiles, etc).
- The accumulation of fallen wood can enhance the growth of the bark beetle, which feeds from it and which can easily become a pest.
- Tree falls destroy the nests of certain bird of prey which build their nest in the top of trees. The only Osprey (*Pandion haliaetus*) population in continental France was badly affected, for example.
- Because food conditions generally improve (availability of buds, young growths, appetising vegetation), hoofed herbivore populations (deer, wild boar, etc) can experience a sudden increase in their populations. Small rodents (e.g. Wood mouse, *Apodemus sylvaticus*) also benefit from better food conditions.
- Due to wind thrown trees on the ground, forest fire risk increased in regions where it was usually marginal.

Wind thrown timber caused by 1999 storms



Source: EEA-ETC/TE 2003 (based on Deutscher Wetterdienst (2000), cited by Münchener Rück (Munich Re Group) in 'Winter storms in Europe' / http://www.unece.org/trade/timber/storm/meeting.htm).

Some consequences of, and responses to, the late December 1999 storms in France

Source: Chris Steenmans.

References

BFH (Federal Research Centre for Forestry and Forest Products), 2002: *The condition of forests in Europe*. 2002 Executive Report. Brussels: United Nations Economic Commission for Europe and European Commission (http://natural-hazards.jrc.it/fires/publications).

'Deutscher Wetterdienst 2000', cited by Münchener Rück (Munich Re Group) in *Winter storms in Europe*.

EEA, 2003: *Europe's environment: the third assessment report* (Environmental assessment report No 10). Copenhagen: European Environment Agency.

McGuire, B., Mason, I., and Kilburn, C., 2002: *Natural hazards and global environmental change*. London: Arnold. (Chapter 2).

Munich Re, 2002: Gale Jeanett: Western/ Central Europe 27–28 October 2002. MRNatCat Poster No 34. Available at http://www.munichre.com.

'Office National des Forêts, Paris': *Rapport annuel 2000*. http://www.onf.fr/doc/pdf/ra00.pdf.

Miró Pérez, J. and Olcina Cantos, J., 2002: 'Temporales de viento fuerte en latitudes medias y altas'. In Ayala-Carcedo, F.J. and Olcina Cantos, J. (ed.): *Riesgos Naturales*. Barcelona: Ariel. (Chapter 37, pp. 661–680).

Biront, T., Drouineau, S., Formery, T., Laroussinie, O., Roman-Amat, B. and Terrasson, D., 2000: 'Expertise collective sur les tempêtes, la sensibilité des forêts et sur leur reconstitution'. *Le Courrier de l'Environnement de l'INRA*, No. 41.

Swiss Re, 2000: 'Natural catastrophes and man-made disasters in 1999'. *Sigma*, No 2. Zurich: Swiss Re.

Fink, A. H., Klawa, M., Pinto, J.G. and Ulbrich, U., 2001: *Three extreme storms over Europe in December 1999*. Köln: Institut für Geophysik und Meteorologie der Universität Köln.

UN/ECE Timber Committee, Geneva. http://www.unece.org/trade/timber/storm/meeting.htm.

Useful links

Title: Eurowind
URL: http://www.eqecat.com/ehelp.htm

Forest fires

Date of the event (1998–2002)	Location	Impact
July 1998	Catalonia (Spain)	About 27 000 hectares burnt, about 600 people affected.
July 1999	Sardinia, Calabria, Liguria (Italy)	More than 32 000 hectares burnt.
Jan–Aug 2000	Galicia, Castile-Leon, Catalonia (Spain)	More than 60 000 hectares burnt from 1 January until 20 August.
July 2000	Samos, Corinth, Aicha (Greece)	About 11 500 hectares burnt, two people killed, 90 homeless.
July 2000	Haskovo, Yambol, Bourgas, Stara Zagora, Plovdiv (Bulgaria)	About 27 000 hectares burnt, seven people killed, 17 injured, 150 homeless.
August 2000	Split, Metkovic, Omis (Croatia)	About 20 000 hectares burnt, one person killed.
August 2000	FYR of Macedonia	About 16 000 hectares burnt.
September 2001	Northern and central Portugal	More than 40 000 hectares burnt.

Source: EM-DAT, 2003.

Forest fires, like drought (which can be a contributing factor), mostly affect Mediterranean and Black Sea countries but occur throughout Europe, including as far north as northern Norway.

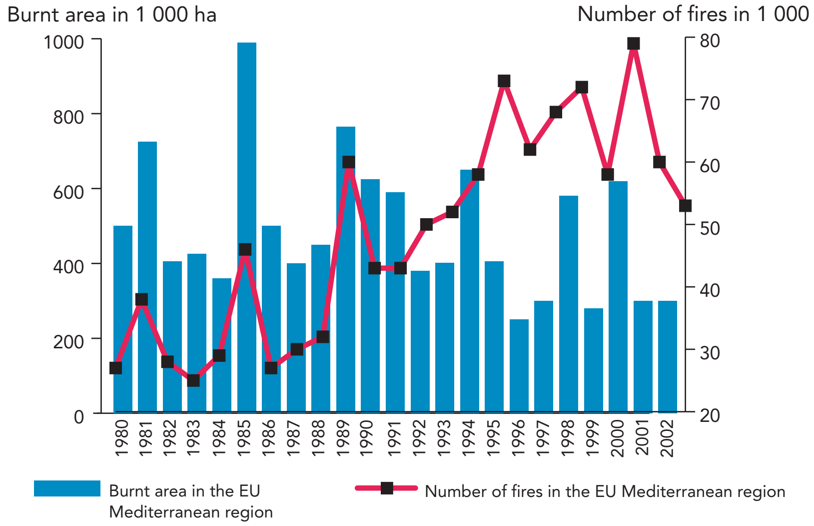
In the five Mediterranean Member States of the European Union — France, Greece, Italy, Portugal and Spain — the area burnt in forest fires has varied between 200 000 and 600 000 hectares a year over the past 20 years (see Figure 3). In that period the total number of fires reported has risen sharply from around 20 000/year to 60 000/year, although this may partly reflect improved reporting procedures.

Between 1998 and 2002, 62 % of forest fires in EEA member countries occurred in the Mediterranean biogeographical region even though this makes up only 14 % of the total European land area (see Map 5). Among EEA countries, Portugal and Spain have the highest number of forest fires and surface area affected.

The summer of 2003 was particularly bad for forest fires in much of southern Europe. Portugal, for example, experienced its worst

Number of fires and burnt areas from 1980 to 2002 in the five EU Mediterranean Member States (France, Greece, Italy, Portugal and Spain)

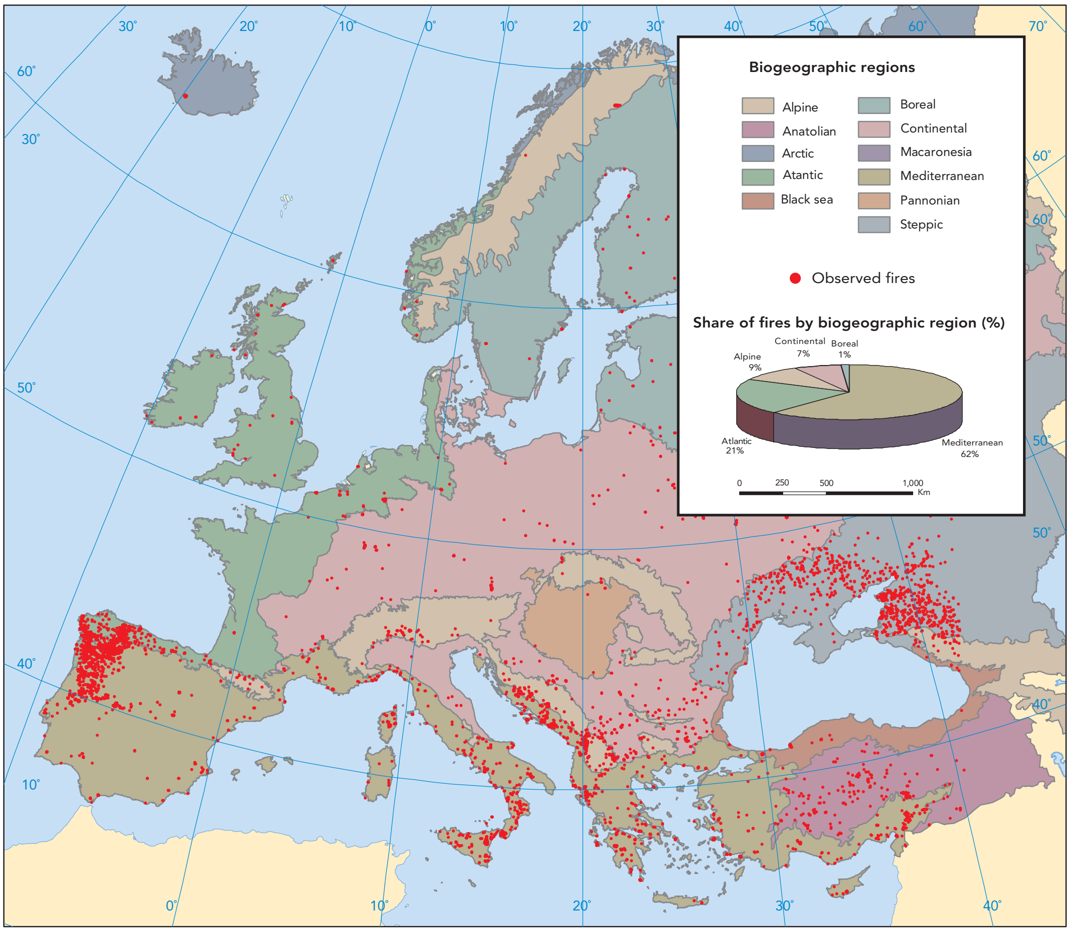
Figure 3



Source: European Commission. Forest fires in Europe — 2002 fire campaign.

Map 5 **Forest fires 1998–2002, based on satellite observations**

Source: EEA-ETC/TE, 2003 (based on ATSR World Fire Atlas. European Space Agency, ESA/ESRIN/ Biogeographic regions (EEA) / Corine Land Cover 90 12/2000 (EEA)), PELCOM 1997 (DLO — Winand Staring Centre).



Note: This map is based on satellite observations of all types of fires, with non-forest fires filtered out as far as possible. Due to inconsistency between data sources, some of the fires shown may not be forest fires. The share of fires by biogeographical region has been calculated only for the territory of EEA member countries.

forest fire season in 23 years as at least 215 000 hectares (5.6 % (2) of its total forest area) burned (see Map 6). The French regions of Var, southern Corsica and Upper Corsica were also seriously affected by fires, with between 1.1 % and 2.5 % of their total area being completely burnt (according to preliminary figures reported up to mid August 2003.

The occurrence of forest fires depends on weather conditions, the amount and characteristics of combustible material and the ignition source. Ignition sources vary greatly, from natural factors, such as lightning, to human factors, such as faulty power lines, agricultural practices, other intentional fires, arson or careless conduct by people using forests for leisure activities. The combination of high temperatures, low moisture content of soils and vegetation, and winds of a certain speed is particularly hazardous. In the great fires of July 1998 in central Catalonia in Spain, which burned almost 30 000 hectares, mean temperatures in the area affected reached 40 ºC, relative humidity was barely 15 % and the wind blew at moderate but persistent speeds (see case study in this chapter). The characteristics of vegetation relevant for forest fires include the combustibility of species and, very important in the development of large fires, the continuity of forest areas.

Forest fires often claim human victims, especially among fire fighters. The summer 2003 fires in Portugal, for instance, caused 15 deaths. Economic losses generated by fires are estimated at 1 000–5 000 euro/hectare burnt (Joint Research Centre, 2001) but this figure may underestimate other costs such as landscape loss, with consequences for rural and eco-tourism, that are much harder to quantify. The Portuguese government has estimated the cost of the summer 2003 fires at 925 million euros.

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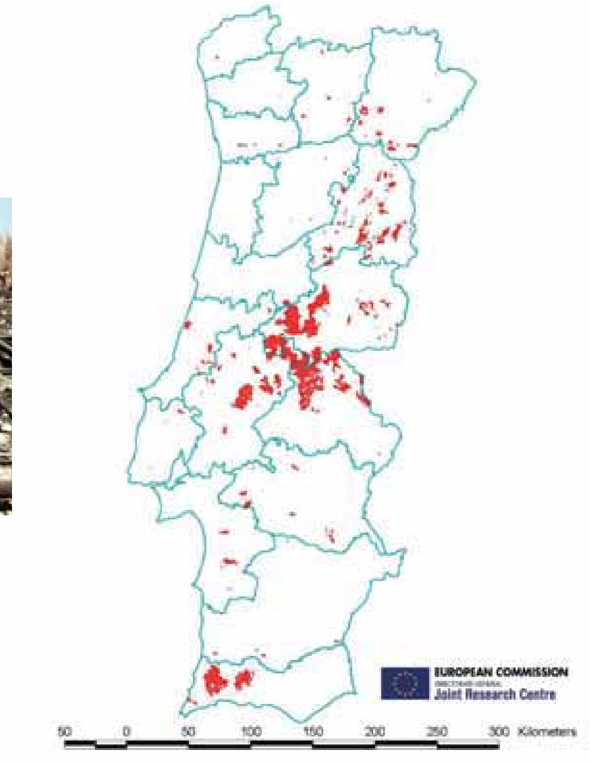
(2) EC/JRC Institute for Environment and Sustainability: The European forest fires information system (EFFIS) results for the 2003 fire season in Portugal up to 20 August. (http://natural-hazards.jrc.it)

Areas burnt in Portugal in 2003 summer season up to 8 August 2003 Map 6

Effects of a forest fire in Portugal

Source: Chris Steenmans



Note: Since the satellite monitoring system used can only detect burnt areas of at least 50 hectares with good accuracy, the total burnt area will certainly be greater than that shown.

Source: JRC/IES 2003.

In environmental terms the most significant impact of forest fires is the destruction of valuable species and their habitats. The summer 2000 heatwave in south-eastern Europe encouraged the spread of fires in Croatia, Bulgaria, Romania and especially Greece where flames reached almost all forests on the island of Samos. Fires also ravaged the Pintos Mountains in northern Greece, home of brown bears and wildcats. The same year, more than 11 000 hectares of high mountain laricio pines (*Pinus nigra ssp. Laricio*) burned in Corsica. In July 2002, fire hit the Natural Park of Guadiana (southern Portugal), created in 1995 to protect the habitat of the Iberian lynx.

However, forest fires can have positive as well as negative environmental impacts, as the following case study shows.

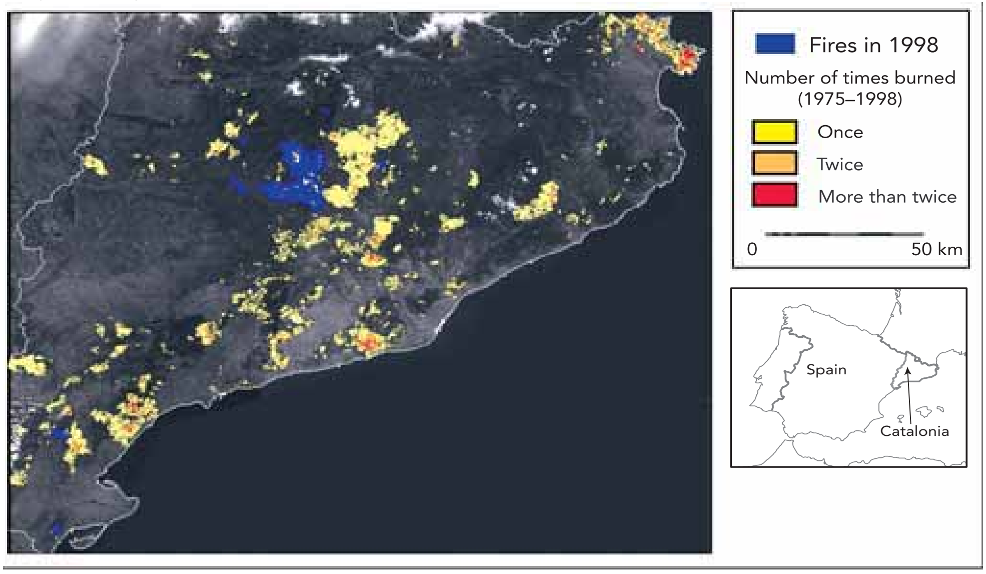
Prevention and public education are essential for reducing forest fires. In France for instance (with the exception of the northern part of Corsica), the area burnt in 1990–2000 was halved from the previous decade by a combination of better forest management practices and stronger fire prevention measures, essentially land use management (*L'état de l'environnement,* 2003). Rural land use planning, especially when aimed at maintaining the traditional land 'mosaic' (forest, pastures, agricultural land) of Mediterranean areas, is perhaps the best option to prevent the propagation of large fires.

Wildfires in Catalonia: effects on biodiversity

As in other areas in the Mediterranean basin, wildfires are an increasing environmental problem in Catalonia's terrestrial ecosystems, most likely as a result of the region's climatic characteristics and land use changes. An analysis of long cartographic data series (1973 to 1998) shows an increasing frequency, extent and intensity of fires in the region, with catastrophic situations in 1994 and 1998.

This trend is increasing impacts on biodiversity. Large fires have changed the dominance of tree species in central Catalonia — from black pine (*Pinus nigra*) to resprouting oaks (*Quercus cerrioides* and the evergreen *Q. ilex*) — and brought about significant land use changes. Landscape changes have been especially intense in drier areas in southern Catalonia, where the abandonment of agricultural land has led to scrubland encroachment. This has produced a more homogeneous landscape, though fires can also increase local landscape heterogeneity as different patches of land recover at different speeds.

Burnt forest areas and fire frequency in Catalonia from 1975 to 1998, derived from LANDSAT images. Only fires larger than 30 ha are included.



Source: CREAF.

Recurrent fires can affect vegetation recovery, as demonstrated in long-term (1975–1998) studies of changes in the Vegetation Index (measuring chlorophyll levels in vegetation) using satellite images. Plant cover has been shown to recover more slowly after a second fire, and also when the interval between fires is very short. Recovery depends too on vegetation type: after the first fire, *Quercus ilex* forests recover faster than pine forests but, after a second fire, the ability to recover declines in *Q. ilex* forests more than in forests formerly dominated by pines.

The effects of fire on species conservation are highly variable depending on the taxonomical group. In Catalonia, the percentage of rare Mediterranean plant species tends to decrease with fire severity, while the percentage of common species increases. In contrast, forest fires favour rare bird species and are detrimental to common bird species, because fires create open areas suitable for the rare, open-habitat species. Many forest-dwelling birds belong to widespread species. In this case study, fire affected rare and common ant species similarly. The number of species recovered quickly after fire. However, the overall quantity of ants decreased sharply and recovered only after many years. High fire frequency could thus promote a critical decrease in ant populations that, in turn, would affect the dispersal of many rare plant species (D. Delgado *et al.*, 2003).

References

Calvo E., Díaz-Delgado R., Lloret F. and Pons X., 2002: 'Wildfires and landscape patterns in the eastern Iberian peninsula'. In *Landscape ecology* 17:745–759.

Díaz-Delgado, R. and Pons, X., 2001: 'Spatial patterns of forest fires in Catalonia (NE of Spain) for the period 1975–1995. Analysis of vegetation recovery after fire'. *Forest Ecology and Management* 147:67–74.

Díaz-Delgado R., Lloret F., Pons X. and Terradas J., 2002: 'Satellite evidence of decreasing resilience in Mediterranean plant communities after recurrent wildfires'. *Ecology* 83:2293–2303.

EEA, 2001. *Sustainable water use in Europe. Part 3: Extreme hydrological events: floods and droughts* (Environmental issue report No 21). Copenhagen: European Environment Agency.

Joint Research Centre, 2001: Natural Hazards (http://natural-hazards.jrc.it/documents/fires/).

Reice, S. R., 2001: *The silver lining. The benefits of natural disasters.* Princeton: Princeton University Press. (Chapters 2–4).

Espelta J.M., Habrouk A., Ordóñez J.L., Retana J. and Solà-Morales F., 2002: 'Regeneration patterns of three Mediterranean pines and forest changes after a large wildfire in NE Spain'. *Ecoscience* 9:89-97.

Díaz-Delgado R., Pons X., Salvador R. and Valeriano J., 2000: 'A semi-automatic methodology to detect fire scars in shrubs and evergreen forests with Landsat MSS time series'. *International Journal of Remote Sensing* 21:655–671.

Smith, K., 1993: *Environmental risk. Assessing risk and reducing disaster.* London: Routledge. (Chapter 10).

Useful links

Title: JRC: Pilot projects on forest fires
URL: http://natural-hazards.jrc.it/fires

Title: Global Fire Monitoring Centre (GFMC)
URL: http://www.fire.uni-freiburg.de

Title: JRC: Global Burnt Area 2000 Project
URL: http://www.gvm.jrc.it/fire/gba2000

Title: Ionia Fire: ATSR World Fire Atlas
URL: http://shark1.esrin.esa.it/ionia/FIRE/AF/ATSR

Title: European Forest Institute
URL: http://www.efi.fi

Droughts

Date recorded as major drought (1998–2002)	Location	Impact
September 1999	Andalusia, Extremadura, Castilla, Murcia, Valencia, Aragon and Catalonia (Spain)	Entire cultivated area affected after one year of drought, huge economic losses (more than 3 bn euro).
March 2000	Cyprus	Worst drought in 30 years.
June 2000	Dolj, Mehedinti, Teleorman, Olt, Constanta, Braila, Vaslui, Botosani (Romania)	Worst drought in at least 50 years, about 26 000 km^2 affected, 40 % of agricultural production at risk, more than 500 m euro in economic losses.
August 2000	Bosnia and Herzegovina	Worst drought in 120 years, about 60 % of agricultural production affected.
May 2002	Sicily, Basilicate, Puglia, Sardinia (Italy)	State of emergency declared.

Source: EM-DAT, 2003.

In Europe, drought mostly affects the Mediterranean region but it occurs throughout most of the continent and is fairly common.

Over the past decade severe episodes have taken place across Europe, from Finland to Portugal and from the United Kingdom to Greece (EEA, 2001). In the summer of 2003, for example, record low water flows were recorded in the River Danube in Bulgaria. Other European rivers, such as the Rhine, also had unusually low water levels. This situation contrasted with heavy flooding the summer before.

Severe droughts have occurred throughout Europe, from Finland to Portugal and from the United Kingdom to Greece (EEA, 2001).

In Europe, droughts do not trigger famines and so do not kill people. However, human, environmental and economic impacts can be devastating, especially when droughts are associated with heatwaves. The fatal effects of heatwaves were demonstrated during the summer of 2003, when temperatures in some areas (France, western Germany, south-west England) climbed to record highs. A heatwave across much of Europe during August 2003, considered the warmest August month on record in the northern hemisphere, claimed possibly as many as 35 000 lives, with France alone recording almost 15 000 deaths, mostly among elderly people (Earth Policy Institute, October 2003).

Droughts can have very heavy economic impacts, especially when they last a long time. In the late 1990s, a drought that particularly affected the central and southern parts of Spain caused losses of more than 800 million euro in the cereal, olive oil and livestock sectors (more than 50 % of the total value of these crops). In the summer of 2002, farmers in southern Italy and Sicily could not irrigate their fields because of the hardest drought in decades. The Italian government had to provide relief funds of 500 million euro. The combination of a long drought and a heatwave that swept across eastern Europe in 2000 reduced the corn output of Romania by one third and significantly diminished agricultural yields in Hungary, Croatia and Serbia (USDA, 2000).

The environmental impacts of droughts can be exacerbated by unsustainable trends in water use. The worst combination appears when drought strikes freshwater ecosystems already weakened by excessive water withdrawals. For example, Lake Iliki, some 100 km northeast of Athens, has been reduced to a third of its original size, partly by a severe drought in 2000 but also as a result of increasing drinking water demand. Likewise, Lake Djoran, located between Greece and the Former Yugoslav Republic of Macedonia (see Map 7), is at risk of drying up, thus threatening one of the richest inland fishing stocks in Europe.

Wetlands are particularly vulnerable to drought. The drought that affected Spain in the first half of the 1990s reduced by 97 % the flooded area of the Natural Park of the 'Tablas de Daimiel', the most important wetland area in the interior of the Iberian peninsula. Here too, water withdrawals, in this case for agricultural purposes, contributed to the loss.

Location of lakes Djoran and Iliki Map 7

Source: EEA-ETC/TE, 2003.

Droughts can cause the deterioration of water quality in rivers, lakes and reservoirs by exacerbating algal blooms that reduce the oxygen available for aquatic species. In the summer of 1999, for instance, these processes affected many lakes in Finland. Droughts may also weaken the resistance of certain plant species to plagues and increase their susceptibility to forest fires, as happened in the Greek island of Samos in the summer of 2000. Finally, drought can threaten the very survival of species in certain areas. The prolonged drought that affected southern Spain in the mid 1990s caused a high mortality rate among maritime pines and severely withered green oak and cork oak forests.

Droughts may also trigger soil erosion, mainly in Mediterranean areas. One way this happens is through a reduction in vegetation cover caused by forest fires or by increased plant mortality due to water stress. In addition, when the soil is very dry, the water infiltration rate decreases. Consequently, if a period of drought is followed by heavy storms, erosion is triggered by surface run-off. The problem is especially acute in the arid and semi-arid Mediterranean areas where the process may lead to desertification.

Although desertification mainly affects Portugal, Spain, Italy and Greece, all 15 European Union Member States have ratified the United Nations convention to combat desertification (UNCCD), adopted in 1994. The convention's main activities include harmonising and sharing information related to desertification and to successful practices and technologies that have been implemented at local or regional level. The EEA has been involved in the desertification information system to support national action programmes in the Mediterranean (DIS/MED), an initiative of the UNCCD secretariat.

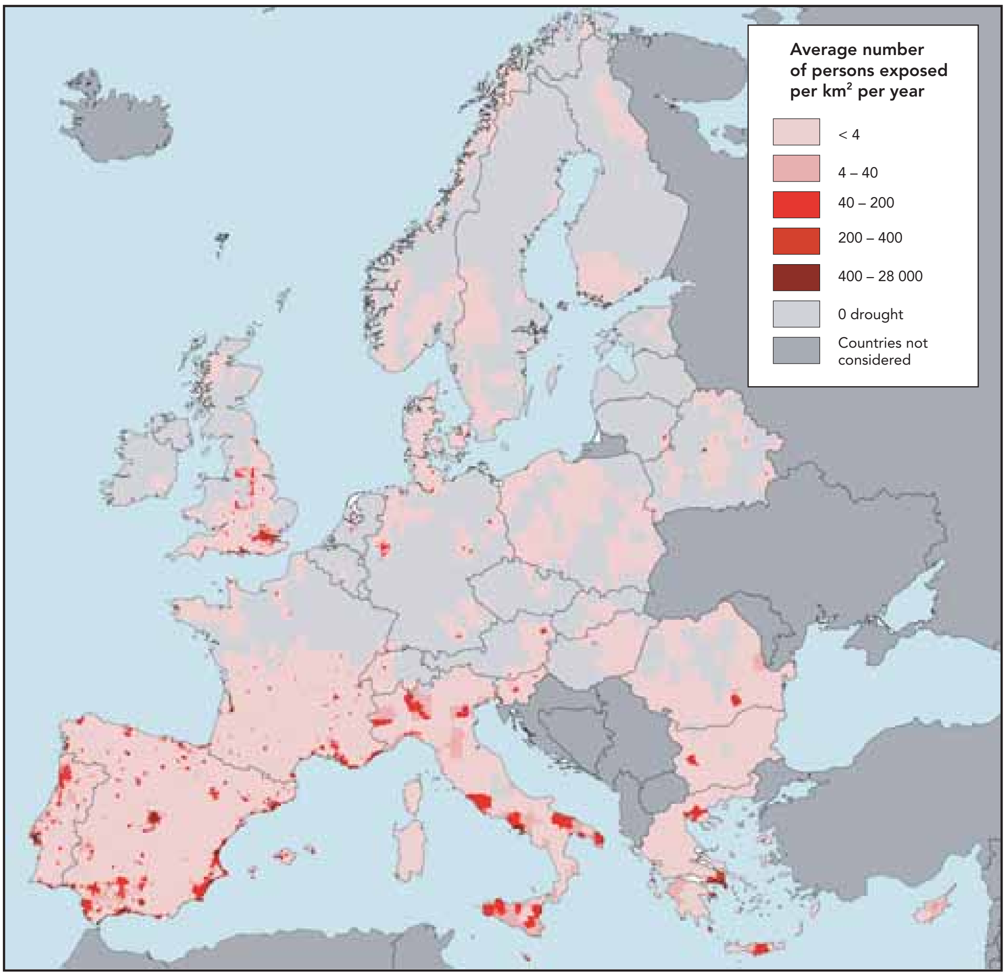
Droughts can also affect countries that under normal conditions are well provided with water resources. The United Kingdom, for instance, suffered droughts in 1993 and 1995 (the latter was especially severe in Yorkshire in northern England) which led to the imposition of water restrictions in certain areas and created financial havoc among water supply companies. In the winter of 2002–2003, water levels in Norwegian and Swedish reservoirs fell to an estimated 10-year low. Hydroelectric production, essential in these countries, was reduced and electricity costs increased sharply, threatening the competitiveness of the forestry and metal industries.

Project to identify population exposed to drought

UNEP/GRID-Geneva, through its project for risk evaluation, vulnerability, information and early warning (PREVIEW), is working on the modelling or mapping of natural hazards such as floods, cyclones, forest fires or volcanoes on the global and regional scales. Drought is one of the most challenging issues. A first stage of research involved UNEP/GRID-Geneva and the International Research Institute for Climate Prediction (IRI) in the elaboration of the Disaster Risk Index developed for the United Nations Development Programme (UNDP/BCPR). The results are to be published by the end of 2003.

The purpose of the collaboration between UNEP/GRID-Geneva and IRI is firstly to achieve a simplified model for estimating the population exposed to drought. The aim is to relate these estimates to the socio-economic context and to explain the number of casualties. The map shows the average population affected by drought in Europe between 1980 and 2000. The southern part of Europe has the highest density of population exposed to the risk of water shortage. The research is ongoing.

Population exposed to droughts in Europe (1980–2000)



UNEP GRID Geneva

IRI International Research Institute for Climate Prediction

0 500 1000 1500 Km

GIS processing and cartography: UNEP/GRID-Geneva
Initial method for drought identification IRI

Data sources: precipitation CRU, population CIESIN
Projection: Lambert Azimuthal Equal-Area
Central meridian 10°E; reference latitude 50°N

References

EEA, 2001: *Sustainable water use in Europe. Part 2: Demand management* (Environmental issue report No 19). Copenhagen: European Environment Agency.

EEA, 2001: *Sustainable water use in Europe. Part 3: Extreme hydrological events: floods and droughts* (Environmental issue report No 21). Copenhagen: European Environment Agency.

Demuth, S., Hisdal, H., Stahl, K. and Tallaksen, L., 2001: 'Have streamflow droughts in Europe become more severe or more frequent?'. *International Journal of Climatology*, 21, 317–333.

IPCC, 2001: *Climate Change 2001*. Cambridge: Cambridge University Press.

Smith, K., 1993: *Environmental risk. Assessing risk and reducing disaster.* London: Routledge. (Chapter 12).

USDA, 2000: *Drought and high temperatures continue in Eastern Europe.* FASonline, June 23. http://www.fas.usda.gov/pecad2/highlights/2000/06/ee.htm

Wilhite, D. (ed.), 2000: *Drought: a global assessment.* London: Routledge (2 vols.).

Demuth, S., 2003: *Droughts in Europe.* Unpublished manuscript. Koblenz: Federal Institute of Hydrology.

Useful links

Title: ARIDE: Assessment of the regional impact of droughts
URL: http://www.hydrology.uni-freiburg.de/forsch/aride

Title: United States Department of Agriculture — Foreign Agriculture Service
URL: http://www.fas.usda.gov/pecad/highlights/2002/10/ee/index_files/eeoctupdate.htm

Title: Unicef: Drought disasters
URL: http://www.unicef.org/drought

Title: Text and annexes of the UN Convention to combat desertification (UNCCD)
URL: http://www.unccd.int/convention/menu.php

Landslides

Date of the event (1998–2002)	Location	Impact
May 1998	Campania region (Italy)	Mudflows swept away hundreds of buildings and killed 160 people.
March 1999	Romania	About 12 landslides, more than 100 homes destroyed, railways and roads damaged.
October 2000	Gondo village (Swiss-Italian border)	Landslides destroyed several buildings, causing 14 deaths.
November 2000	Slovenia	About 25 hectares of forest swept away.
November 2001	Camlihemsin, Cayeli, Ardesen, Pazar, Findikli, Rize (Turkey)	Landslides triggered by torrential rains, nine people killed, about 600 evacuated.

Source: EM-DAT, 2003.

In Europe, most catastrophic landslides are associated with heavy storms and flooding, coupled with soil erosion on mountain slopes (EEA, 2003). In the Nordic countries, however, the main factor is the widespread presence of soft sediments of glacial origin that become a threat when mobilised.

The Mediterranean basin and the mountain regions of central and eastern Europe are particularly vulnerable to landslide events.

Most of western Europe (with the partial exception of France) suffers relatively few significant landslides. By contrast, the Mediterranean basin (e.g. southern Italy and the eastern Iberian Peninsula) and the mountain regions of central and eastern Europe are particularly vulnerable to these events. High tectonic activity and relatively recent sand and clay deposits increase these regions' susceptibility to landslides, and this vulnerability increases if urbanisation and poor forest management are present (Alexander, 1993).

Landslides refer to all kinds of mass movements involving soil, rocks or mixed materials (CALAR, 2000). They can be very destructive (3) and cause human casualties, heavy economic damage and landscape degradation, especially in mountain areas. Landslides tend to occur in combination with one or more of the following factors: reliefs with steep slopes; unstable materials; high water content of the soil; heavy rainfall; seismic activity; erosion; and deforestation. Human activities, such as the construction of roads, buildings, etc, can also undermine the base of slopes and contribute to landslides (McGuire, Mason and Kilburn, 2002).

In Italy, for example, landslides increased substantially during the second half of the 20th century, mostly because of urbanisation and agricultural land abandonment (Martinis, 1987). It is estimated that as many as half of Italian cities are at risk from such events. Map 8 shows the occurrence of landslides in Italy between 1998 and 2001. No such picture exists for the whole of Europe. However, there is also an increasing frequency of landslides in Spain, and these are estimated to have caused the national economy losses amounting to some 36 million euro/year during the 1990s (Ayala-Carcedo, 2002).

The impacts of landslides are usually underestimated, partly because most events are relatively small and also because damage often tends to be subsumed under the more general impacts of flooding, with which landslides are frequently associated.

The case study in this chapter focusses on two factors that helped trigger one of the worst disasters to happen in Slovenia in recent years. The landslide episode occurred after heavy rainfall; the region's seismic activity probably also contributed.

Sustainable land use planning is increasingly seen as an effective response to landslides, as well as a measure to help prevent them. Landslide maps showing the most vulnerable slopes are available in most countries, although often not with the level of detail needed. Monitoring of slope behaviour,

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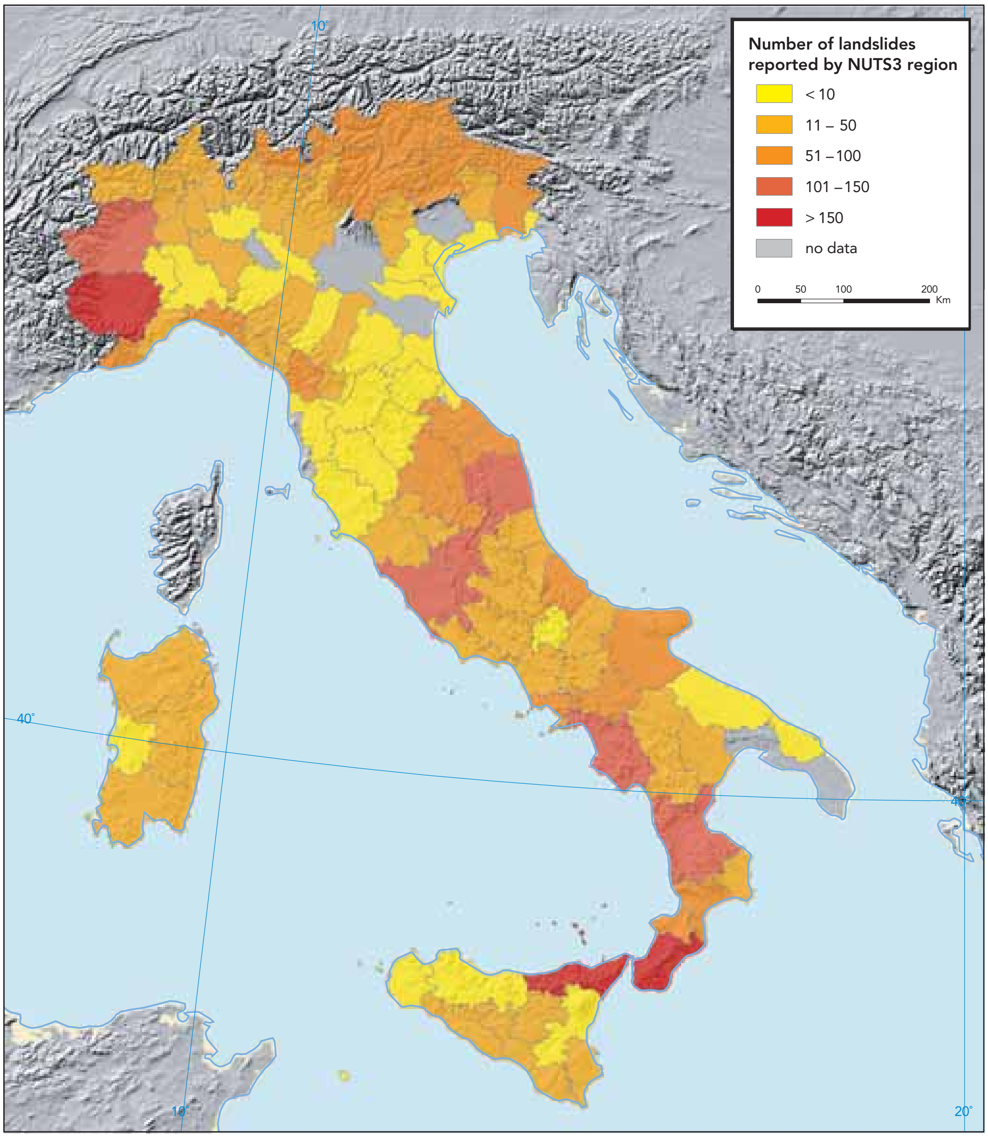
(3) The World Landslide Inventory has produced a scale of landslide impact severity based on velocity that ranges between five metres/second (very rapid, dangerous and highly destructive) and less than two centimetres/year (no damage likely provided that structures are well-built).

especially during periods of intense rainfall, is also important for the design and implementation of warning and evacuation plans.

Number of landslides reported in Italy (1998–2001) Map 8



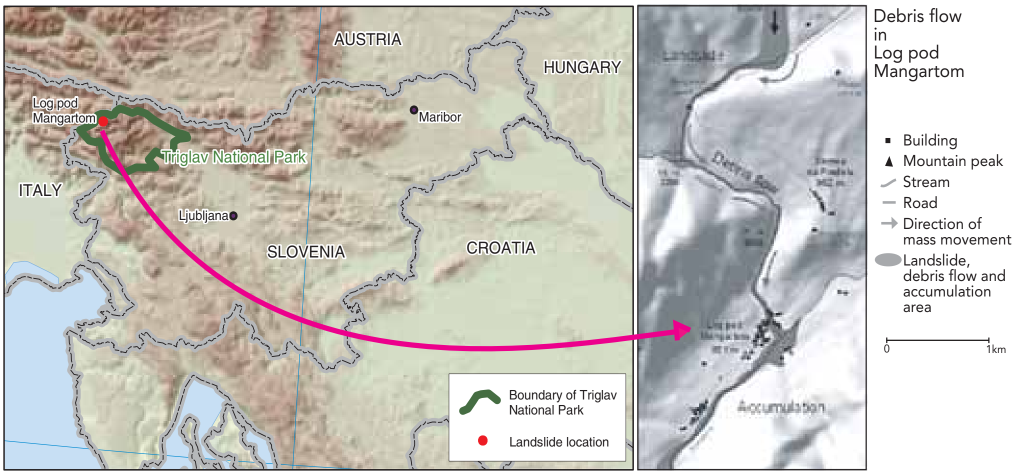
Source: EEA-ETC/TE, 2003, based on Gruppo nazionale per la difesa dalle catastrofi idrogeologiche del consiglio nazionale delle ricerche (National group for defence against hydrogeological disasters of the national research council) (http://www.gndci.cnr.it/) / Digital elevation model (GISCO).

In Italy the number of landslides has increased dramatically over the past 50 years mainly due to urbanisation and agricultural land abandonment.

Landslides in Slovenia, 2000

The Stože landslide on 15 November and the Predelica torrent debris flow on 17 November 2000 were the worst natural disasters in Slovenia in recent years.

The events mainly affected the alpine village of Log pod Mangartom, located in the Koritnica valley within the Triglav National Park in the Julian Alps (see map).



A) Location of the landslide

B) Debris flow

Sources: A) EEA ETC/TE, 2003; **B)** Map contents and cartography Blaz Komac, Matija Zorn, Anton Melik Geographical Institute of Scientific Research Centre of SASA, Ljubljana, 2003.

The landslides were preceded by heavy precipitation during the autumn, especially at the beginning of November (400 % above the average for that period), which also caused the flooding of many rivers, streams and torrents. Other factors contributing to the landslides were the specific geological composition of the ground and, probably, seismic activity in the zone.

The first landslide flowed down the slopes in the area of the Mangart torrent at a fairly rapid speed of almost one metre per second, sweeping away more than 25 hectares of forest. The landslide did not threaten the village but it reached the confluence of the Mangart and Predelica torrents. Its length was about one kilometre, its average width approximately 100 m and its volume about 600 000 m^3. The map above shows the debris flow of the Stože landslide.

The second landslide flowed downhill from an altitude of 1 600 m to 1 200 m. There it accumulated for several hours, becoming saturated by the waters of the Mangart torrent, supplemented by heavy rain. Following this, the debris flow moved extremely quickly, travelling for several kilometres. It is estimated that some million cubic metres of materials moved downwards along the bed of the Mangart torrent and poured along the beds of the Koritnica and Predelica torrents, burying part of the village of Log pod Mangartom under tonnes of mud.

The 140 inhabitants had been evacuated after the first landslide, but seven people who had returned to their homes were killed when the debris flow from the second landslide struck the village (these casualties are not recorded in the EM-DAT database, which covers only accidents with at least 10 deaths). About 700 000 m^3 of materials were deposited on the village and surrounding area, covering approximately 50 hectares, mainly grassland. The area was virtually cut off for a few weeks and the residents did not return until the following spring.

The landslide destroyed several residential and industrial buildings and damaged the electricity network, a power plant and water reservoirs. The local economy, which depends largely on sheep products and tourism, was seriously affected. Total economic losses amounted to 36 million euro.

Three years after the event the affected area is still bare of vegetation. The torrents' forms have changed and the amount of water they carry has increased. As a result of the loss of vegetation cover and the modified water regime, the erosion process in the area has accelerated.

References

Alexander, D., 1993: *Natural disasters.* London: UCL Press. (Chapter 4).

Ayala-Carcedo, F.J., 2002: ‘Análisis de riesgos por movimientos de ladera’, in Ayala-Carcedo, F.J. and Olcina Cantos, J. (ed.): *Riesgos Naturales.* Barcelona: Ariel. (Chapter 18, pp. 379–409.

CALAR project: Concerted action on forecasting, prevention and reduction of landslide and avalanche risks (2000, DG Research), http://www.swedgeo.se/calar/.

EEA, 2003: *Europe’s environment: the third assessment report* (Environmental assessment report No 10). Copenhagen: European Environment Agency.

Hervás, J. (ed.), 2003. *NEDIES Project — Lessons learnt from landslide disasters in Europe.* Report EUR 20558 EN. Luxembourg: Office of Official Publications of the European Community.

Martinis, B., 1987: *Le Calamità Naturali in Italia.* Milano: Mursia Editore. (Chapter 5).

McGuire, B., Mason, I., and Kilburn, C., 2002: *Natural hazards and global environmental change.* London: Arnold. (Chapter 4).

Melik, A. http://www.zrc-sazu.si/gi/log.htm.

Oštir, K., Tan i , Z. and Veljanovski, T.: *Log pod Mangartom Landslide, Slovenia Charter ‘Space and Major Disasters’*, Final Report.

Smith, K., 1993: *Environmental risk. Assessing risk and reducing disaster.* London: Routledge. (Chapter 8).

Triglav National Park, Slovenia. http://www.sigov.si/tnp.

Zorn, M., 2002: ‘Rockfalls in Slovene Alps’. *Acta Geographica*, 42. Geografske Zbornik, pp.160.

Useful links

Title: CNR-GNDCI web site: The AVI project
URL: http://avi.gndci.cnr.it/welcome_en.htm

Title: Kingston University
URL: http://www.kingston.ac.uk/~ku00323/landslid/slides.htm

Title: Bureau de recherches géologiques et minières (BRGM) — Site sur les mouvements de terrain
URL: http://www.bdmvt.net

Title: International Landslide Research Group
URL: http://ilrg.gndci.pg.cnr.it

Title: USGS — National Landslide Information Center
URL: http://landslides.usgs.gov/html_files/nlicsun.html.

Avalanches

Date of the event (1998–2002)	Location	Impact
February 1999	Galtür, Valzur (Austria)	About 40 people killed.
February 1999	Evolene (Switzerland)	Several parallel avalanches killing 12 people.
March 2000	Kitzsteinhorn (Austria)	Twelve people killed.

Source: EM-DAT, 2003, and Swiss Federal Institute for Snow and Avalanche Research.

Avalanches are generally natural events and the majority occur without causing damage or even being noticed. The Alps, stretching in a crescent from southern France up through Switzerland, Liechtenstein and northern Italy eastwards into southern Germany, Austria and finally Slovenia, suffer more avalanches than any other region in the world (4). Alpine avalanches kill around 100 people a year (average for the past 30 years). In recent history the winter of 1998/99 was especially deadly, with the heaviest snowfall in the Alpine region for 50 years triggering numerous fatal avalanches in particular in Austria, France, Switzerland, Italy and Germany.

Figure 4 shows the number of deaths caused by avalanches for the period 1997/98 to 2001/02 in member countries of the International Commission for Alpine Rescue (ICAR), five of which are, or will be from May 2004, Member States of the European Union. Despite the significance of avalanches in the countries affected, data gathering is difficult since there is no agreed way to collect data on fatalities, damage and economic losses across Europe.

Avalanche formation is the result of a complex interaction between terrain, snow pack and meteorological conditions. While catastrophic avalanches generally occur naturally, some are triggered by skiers.

The growth in winter sports over recent decades is increasing the risk of avalanches caused by skiers while the related development of tourism infrastructure is raising the potential economic cost of any damage caused. However, the available data indicate that in fact neither the number of skier avalanches nor the overall cost of avalanche damage have risen in the past few decades.

In environmental terms avalanches can cause soil erosion, break trees or even destroy whole forests. But, despite their destructive force, avalanches have a beneficial influence on several aspects of the ecosystem, as a new study for the Swiss Federal Institute for Snow and Avalanche Research (SLF) shows (Brugger, 2003).

When an avalanche starts above a forest big trees can break off, increasing the amount of light reaching the ground. Levels of nutrients and water also rise in the absence of the dominant trees that would have used these resources. These changes can create the conditions that many plant species need for growth, thereby allowing a different plant population to develop. The baby plants are sheltered by the snow cover or are flexible enough not to get destroyed by subsequent avalanches.

The biodiversity in avalanche tracks is often high, up to three times higher than in the surrounding forests. The frequency of avalanches is highest in the centre of an avalanche track. Also, there are areas where the snow accumulates and others where it gets eroded. Because of these factors, a variety of habitats develop within a small area. The more avalanches of various intensities that occur, the higher the variety becomes compared with the surrounding area.

Another study by SLF examines for the first time the effects of avalanches on alpine tourism, a very important economic factor for the region and in some areas the only source of income for the locals. Its main

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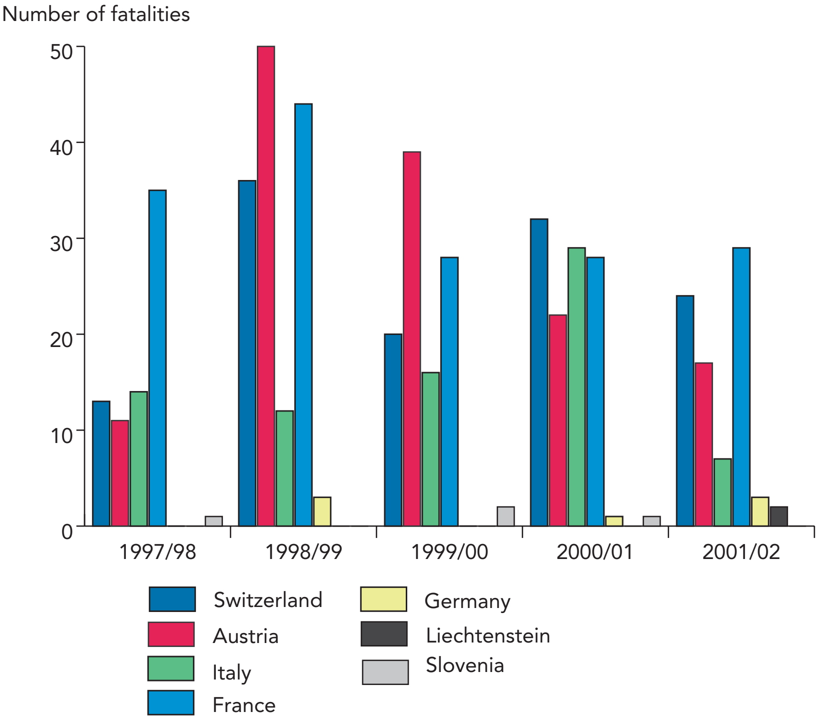
(4) Based on a report prepared by Brunel University, London. For further information see: http://www.brunel.ac.uk/depts/geo/iainsub/Disasters/aval.html

Human casualties caused by snow avalanches in Switzerland, Austria, Italy, France, Germany, Liechtenstein and Slovenia in the winters of 1997–98 to 2001–02

Figure 4



Source: ICAR (International Commission for Alpine Rescue).

finding is that tourists react strongly to such events. Natural disasters and the consequent media coverage, often slightly exaggerated, are the main causes of loss of tourism revenues. Reductions in overnight stays in the alpine region are still noticeable one year after a disaster, though the number of day-trippers recovers after a relatively short period. Deaths on the roads or in residential areas lead to the biggest falls in the numbers of visitors. Communication seems to be the most important factor in improving the situation, suggesting the need for professional public relations during an event or crisis (Nöthiger, 2003).

As in the case of other hazards, policy responses to snow avalanches require a combination of measures based on an integrated approach to risk assessment and management.

To protect human lives, warning systems and public education are essential. Thus, most countries publish maps of areas where snow avalanches occur and weather services issue avalanche alerts several times a day through the winter. Structural measures to prevent impacts on the built environment may include snow fences in the zones where avalanches tend to start, deflecting and retarding systems along known avalanche pathways, and direct protective measures for houses, roads and railways (Smith, 1993). Reforestation of the most dangerous slopes is an option with many side benefits. However, soils that are degraded by previous events and the long period needed to grow well-developed tree barriers may hamper the development of this approach.

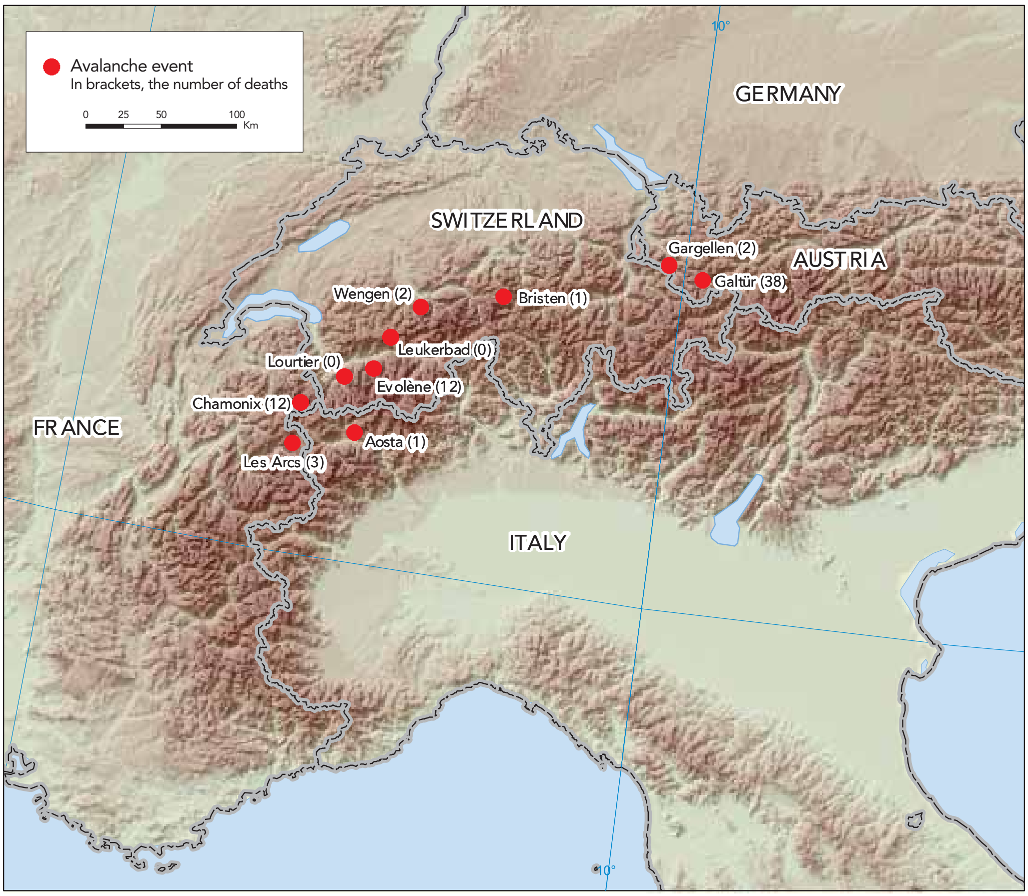
Fatal avalanches in the Alps, 1999

The Alps are the most densely populated high mountain range in the world and attract around 120 million visitors per year (10 % of the world's tourism revenue).

Catastrophic avalanches occurred in early 1999 in exceptional climatic circumstances combining heavy snowfall, snow accumulation due to stormy winds and unstable snow layering.

A state of emergency was declared in several Alpine regions in February 1999. The snow cover increased by more than five metres in less than five weeks in many parts of the Alps. At the same time, the winter sport resorts were very busy, which increased the danger of avalanches. During February 1999, hundreds of avalanches descended within a few days, some of them hitting several ski resorts and mountain villages in the French, Italian, Swiss and Austrian Alps. At least 100 people were killed and many others injured. The most affected villages were Ischgl, Valzur and Galtür in the Austrian Paznauntal (38 dead), Chamonix in the Savoyard Alps (12 dead) and the Swiss village of Evolène (12 dead).

Casualties of 1999 avalanches



Source: EEA-ETC/TE, 2003 (based on *Avalanches in the European Alps, February 1999*, Partner Research, Partner Reinsurance Company Ltd.).

Various municipalities and even entire valleys were cut off for several days as walls of snow blocked communication links. Tens of thousands of tourists and residents were stranded in the Alps and more than 10 000 were evacuated by helicopter. Due to difficulties in removing the snow and/or the risk of avalanches, major international transport links such as the highways and railways of St. Gothard, Tauern, Arlberg, San Bernardino and Grand St. Bernard were temporarily closed. Homes, industrial buildings, mountain stables and transport and energy networks were damaged. In Switzerland alone, losses amounted to almost 400 million euros.

While complete security against natural hazards can never be achieved, the extensive protection measures against avalanches developed in the Alps over recent decades proved fairly effective in preventing greater damage. These cover organisational aspects such as avalanche forecasting, emergency plans and evacuations; research and management aspects such as avalanche mapping and land-use planning; and technical measures such as construction of steel bridges, wire nets, deflecting and catching dams, etc. Last but not least they also include the maintenance of stable mountain forests, which is the cheapest and most secure means of preventing snow avalanches, especially when avalanches start in forested areas. The trees retain the snow and stabilise the snow pack. About 1 000 km^2 of Switzerland's forest area serves primarily as a protection against avalanches and rockfalls.

Protective measures (tunnels) diminish the impact of avalanches. Goppenstein, Switzerland, February 1999.

Source: Swiss Federal Institute for Snow and Avalanche Research SFL, Davos, Switzerland.

References

Brugger, S., 2003: *Auswirkungen von Lawinen auf die Vegetation: Eine Studie im Dischmatal.* Unpublished Report. Davos, Switzerland.

'Bundesamt für Umwelt, Wald und Landschaft' (BUWAL), 2001: *Schriftenreihe Umwelt nr. 323 Lawinenwinter 1998/1999.* Bern.

Colombo, A.G. (ed.), 2000: *NEDIES Project — Lessons learnt from avalanche disasters.* Report EUR 19666 EN. Luxembourg: Office of Official Publications of the European Community.

'Deutschen Alpenverein'. http://www.alpenverein.de/pdf/992f_nun.pdf

Eidg. Institut für Schnee- und Lawinenforschung (Hrsg.), 2000: *Der Lawinenwinter 1999. Ereignisanalyse.* Davos, Switzerland: Eidg. Institut für Schnee- und Lawinenforschung.

European Commission, Brussels. http://europa.eu.int/comm/research/rtdinfo/en/24/07.html.

Bartelt, P., Foehn, P. and Stoffel, M., 2002: *Formation and forecasting of large (catastrophic) new snow avalanches.* Proceedings of the International Snow and Science Workshop, 2002, Penticton, B.C.

Bründl, M. and Fuchs, S., 2003: 'Damage potential and losses resulting from snow avalanches in settlements of the canton of Grisons, Switzerland', in McGuire, B., Mason, I. and Kilburn, C., 2002: *Natural hazards and global environmental change.* London: Arnold.

Laternser, M., 2002: *Snow and Avalanche Climatology of Switzerland.* Dissertation 14493. Zürich: Swiss Federal Institute of Technology.

Nöthiger, C.J., 2003: *Naturgefahren und Tourismus in den Alpen, untersucht am Lawinenwinter 1999 in der Schweiz.* Dissertation. Zürich: University of Zürich.

Ammann, W. and Schilling, A., Swiss Federal Institute for snow and avalanche research SLF, 2003: Personal communication, June.

Jamieson, J.B., Schneebeli, M. and Schweizer, J., 2003: 'Snow avalanche formation', in *Reviews of Geophysics.*

Useful links

Title: Institute of Geography and Earth Sciences at the University of Wales, Aberystwyth
URL: http://www.aber.ac.uk/iges/cti-g/hazards99/avalanche/haz.html

Title: Colorado Geological Survey
URL: http://geosurvey.state.co.us/avalanche/US_World_stats/2002-03/US2002-03.html#ikarstats

Title: Météo France
URL: http://www.meteo.fr/meteonet/temps/activite/mont/mont.htm

Title: SLF Davos
URL: http://www.slf.ch/welcome-en.html

Title: Avalanches in Austria
URL: http://www.brunel.ac.uk/depts/geo/iainsub/Disasters/aval.html

Earthquakes

Date of the event (1998–2002)	Location	Impact
August 1999	Izmit, Kocaeli, Yalova, Golcuk, Zonguldak, Sakarya, Tekirdag, Istanbul, Bursa, Eskisehir, Bolu (Turkey)	Magnitude 7.4 on Richter scale, 30 % of Turkey's area and 45 % of the population affected, more than 17 000 people killed, about 600 000 homeless, more than 15 bn euros in economic losses.
September 1999	Athens suburbs of Menidi, Metamorphosis & Thracomekedones (Greece)	5.8 on Richter scale, about 140 people killed, more than 30 000 buildings partly or totally damaged, about 70 000 people homeless, high economic losses of about 650 m euros.
November 1999	Düzce, Bolu, Kaynasli (Turkey)	7.2 on Richter scale, about 850 people killed, more than 50 000 people homeless, about 10 bn euros in economic losses.
February 2002	Bolvadin (Afyon province, Turkey)	6.2 on Richter scale, about 45 people killed and 2 000 affected, hundreds of buildings damaged.
October 2002	San Giuliano di Puglia (Campobasso province, Italy)	5.4 on Richter scale, 30 people killed (mostly children in a school that collapsed), more than 8 000 people homeless, about 800 m euros in economic losses.

Source: EM-DAT, 2003.

In Europe, earthquakes have killed far more people than any other extreme event and have caused extensive damage. Europe's major earthquake-prone areas are in the Mediterranean and Black Sea basins, along the active fault lines between the Eurasian and African plates.

The most dramatic events in recent decades include the 1977 earthquake in Romania, which seriously affected the capital, Bucharest; the 1980 earthquake in southern Italy, which killed 4 500 people and left more than a quarter of a million homeless; and the 1997 succession of earthquakes in central Italy, which badly damaged, among other things, the Basilica of Saint Francis of Assisi and its natural environs.

Several major earthquakes have occurred over the past five years. By far the most powerful and destructive of these was the Izmit earthquake in Turkey in August 1999, which killed an estimated 17 000 people and caused more than 15 billion euro in losses (see case study in this chapter). The following month a seismic tremor struck the northern neighbourhoods of Athens, killing around 140 people and leaving more than 60 000 homeless.

Earthquakes cannot be prevented, so adaptation is the main response available.

More recently, in October 2002 San Giuliano di Puglia in southern Italy suffered an earthquake that caused 30 deaths and left 3 000 people homeless. Most of the victims were small children who died when their school collapsed (EEA, 2003). The latest major earthquakes took place in Turkey in April 2003 and in Algeria in May 2003. The effects of the latter event were felt in the Balearic Islands in the form of a small tsunami that sank several recreational boats.

An earthquake can sometimes trigger one or more subsequent earthquakes through a mechanism called stress transfer. Under this process, seismic waves from previous events add stress to nearby fault lines, thus increasing the chance of future earthquakes (Swiss Re, 2000). For example, the November 1999 earthquake that killed almost 1 000 people in Düzce in Turkey appeared to be related to the Izmit earthquake three months earlier.

Map 9 shows the location of the major earthquakes in the eastern Mediterranean between 1998 and 2002 and the number of casualties recorded.

Earthquakes cannot be prevented so adapting to them, especially concerning the built environment, is the main response available. In 1996, the European Commission launched a programme to enhance public protection against earthquakes that stresses the importance of international cooperation and the implementation of building standards (known as Eurocodes) for seismic-prone areas in all EU Member States. For

Population density and number of deaths from major earthquakes in the eastern Mediterranean (1998–2002) Map 9

Source: EEA-ETC/TE, 2003 (based on EM-DAT / Gridded Population of the World (GPW), Version 2. Palisades, NY: CIESIN, Columbia University. http://sedac.ciesin.org/plue/gpw).

example, a new city code passed in the city of Barcelona (not particularly exposed to events of large magnitudes) requires all new buildings to be designed to withstand earthquakes of up to a magnitude of seven on the Richter scale.

The Izmit earthquake, Turkey 1999

During the 20th century there were numerous large earthquakes in western Turkey along the North Anatolian Fault (NAF), which is considered one of the most seismically active zones in the world and also one of the best studied.

The so-called Izmit earthquake occurred on 17 August 1999 and had a magnitude of 7.4 on the Richter scale. The earthquake's epicentre was located in the Gulf of Izmit, near the town of Gölcük (see Map 9), and ruptured a section of the NAF more than 110 km long. Despite its vulnerability to earthquakes the region is home to one-third of Turkey's 65 million population and constitutes the country's industrial corridor, accounting for 40 % of its manufacturing production. The region underwent rapid growth as people, mainly from rural areas, were attracted by its employment and education opportunities. Land development occurred quite rapidly, overwhelming local government's ability to control it and enforce building codes. Consequently most buildings were poorly constructed. This resulted in catastrophic levels of damage and loss of life as people were trapped in the collapsed buildings.

The impacts of the earthquake were mostly concentrated around 40 km of the epicentre but were felt as far away as Istanbul (especially the neighbourhood of Avcilar), more than 90 km from the fault line.

Damage affected a total area of 2 000 km^2 and was caused directly by the surface fault opening and shaking, flooding in areas that subsided and loss of bearing strength in the soil under buildings.

Telecommunication lines and water, road and rail arteries were disrupted, hindering the emergency response. The earthquake affected several industries, including the country's largest oil refinery, which burned for six days. Several incidences of hazardous chemical releases were identified.

Local water and wastewater systems were severely damaged, particularly in areas that suffered ground settlement. The water supply network throughout the region was drained empty by leaks. Failed water supplies meant that some emergency shelters did not have sanitation for several days after the earthquake. Water had to be trucked from reservoirs to damaged towns.

The Richter scale for measuring the magnitude of earthquakes is logarithmic. This means that an increase of one magnitude unit represents a ten-fold increase in measured amplitude. Thus, a magnitude 7 earthquake is 10 times larger than a 6, 100 times larger than a magnitude 5 and 1 000 times as large as a 4 magnitude. The worst earthquake ever recorded had a magnitude of 8.9.

The 'domino effect' of a disaster (Izmit earthquake)

Source: EQE International (http://www.eqe.com/revamp/izmit/).

More than 120 000 housing units were heavily damaged or collapsed, leaving approximately 600 000 people homeless. Estimates of the total economic loss vary between 15 and 20 billion euro (7–10 % of Turkey's GDP).

The earthquake caused subsidence of the Marmara Sea coastline by about three metres and the shoreline shifted inland by 100 to 300 metres in some places, causing destruction and flooding. A small tsunami formed after the earthquake in the Izmit Bay.

The Izmit earthquake has probably had lasting consequences on the way risk is perceived in Turkey. The disaster offers lessons for risk managers on how rapid urbanisation and economic growth can raise the human and economic costs of natural disasters to catastrophic proportions.

References

Alexander, D., 1993: *Natural disasters.* London: UCL Press. (Chapter 2).

Altinok, Alpar, B., Ersoy, Y.S., Kuran, U. and Yalciner, A.C., 2001: *Historical tsunamis in the Sea of Marmara.* ITS 2001, Proceedings, Session 4, Number 4–2 p. 527.

Cranswick, E., Erdik, M., Frankel, A., Meremonte, M., Mueller, C., Overturf, D., Ozel, O., Safak, E., 1999: *Earthquake damage, site response, and building response in Avcilar, West of Istanbul, Turkey.*

Eurocodes, http://www.eurocode1.com/en.

EEA, 2003: *Europe's environment: the third assessment report* (Environmental assessment report No 10). Copenhagen: European Environment Agency.

Middle East Technical University: *Background and overview of the Marmara Region earthquake.*

Proceedings ITU-IAHS International conference on the Kocaeli earthquake 17 August 1999: *A scientific assessment and recommendations for re-building.* Karaca, M. and Ural, D. N. (ed.), Istanbul Technical University. pp. 193–204.

Risk Management Solutions, Inc., 1999: *Earthquake risk in Turkey* http://www.riskinc.com/Publications/Turkey_EQ.pdf.

Risk Management Solutions, Inc., 2000: *Event Report: Kocaeli, Turkey earthquake.* p. 16.

Smith, K., 1993: *Environmental risk. Assessing risk and reducing disaster.* London: Routledge. (Chapter 6).

Swiss Re, 2000: 'Natural catastrophes and man-made disasters in 1999'. *Sigma,* No. 2. Zurich: Swiss Reinsurance Company.

Useful links

Title: European-Mediterranean Intensity Database (EMID)
URL: http://emidius.mi.ingv.it/EMID

Title: Significant Earthquake Database Search
URL: http://www.ngdc.noaa.gov/seg/hazard/sig_srch.shtml

Title: USGS Earthquake Hazards Program: National Earthquake Information Center
URL: http://neic.usgs.gov

Title: BGR/Seismic Data Analysis Center (SDAC)
URL: http://sdac.hannover.bgr.de/index2.html

Title: IRIS Seismic Monitor
URL: http://www.iris.edu/seismon

Oil spills

Type of technological accident	Date of the event (1998–2002)	Location	Impact
Marine oil spill by the tanker *Erika*	December 1999	Atlantic coast of France	20 000 tonnes of oil spilled, 400 km of coast polluted, 45 000 birds found dead.
Marine oil spill by the tanker *Volgoneft*	December 1999	Marmara Sea (Turkey)	4 300 tonnes of oil spilled.
Marine oil spill by the tanker *Baltic carrier*	March 2001	Baltic Sea (Denmark)	2 700 tonnes of oil spilled, about 3 000 birds found dead.
Marine oil spill by the tanker *Prestige*	November 2002	Atlantic Ocean off the Galician coast (Spain)	More than 35 000 tonnes spilled, with a similar amount left inside the sunken tanker. Almost 20 000 birds found dead, several hundred kilometres of coast polluted in Spain and France.

Source: EM-DAT, 2003.

Two major oil spills occurred in Europe between 1998 and 2002, both of them involving tankers that were old and unable to withstand severe weather. In December 1999, the *Erika* sank in the Atlantic and the resulting spill contaminated more than 400 km of France's Atlantic coast. In November 2002, the wreck of the *Prestige* leaked high-sulphur oil that polluted the western and northern shores of Spain as well as the French coast, causing one of the worst ecological disasters in European waters (see case study).

The occurrence of accidents correlates strongly with the age of the vessel. In 2000, of the global fleet of approximately 8 800 tankers transporting oil and oil-related products, about 17 % were more than 50 years old, and more than 34 % were 25 years old. It is estimated that the risk of sinking is multiplied by 25 when ships are 20 years old or more.

Moreover, more than half of the world oil fleet navigates under the so-called 'flags of convenience', which usually mean that ships are subject to less stringent safety measures.

In 1998, the total amount of oil and oil products transported by sea reached the two billion-tonne/year mark (more than 40 % of total maritime traffic). The European Union accounts for 27 % of this traffic, with 90 % of Europe's oil arriving by sea. Around 3 000 tankers and other ships — around one-third of the world fleet — transport oil and oil products to and from European (5) ports (European Commission, DG Energy and Transport, 2003).

These figures help to explain why the risk of oil tanker accidents is particularly high in Europe and why some of the worst recent catastrophes (eg, *Erika* and *Prestige*) have occurred in European waters. The latest such accident is the spill of more than 80 000 litres of fuel by a Chinese freighter on the southern coast of Sweden in June 2003.

Oil spills do not affect only the marine environment. European inland waterways are also polluted with oil. For example, the lower course of the Danube River as it enters Romania and Bulgaria and heads towards the Black Sea is dotted with oil and oil wastes resulting from heavy river traffic.

Oil spills produce two main types of impacts on marine ecosystems: impacts produced by physical causes (for example, the smoothening of surfaces by oil); and impacts produced by the toxicity of oil or the specific oil product on marine flora and fauna, including commercial fish species. The presence of oil and of oil mixed with sand ('mousses') has substantial negative impacts on tourism and on shellfish harvesting that are very costly to redress because cleaning up is a long and arduous task. In summary, the ecological and economic impacts of oil spills threaten many traditional activities in affected areas.

In 2000, out of 8 800 tankers transporting oil and oil related products throughout the world, about 17 % were more than 50 years old, and more than 34 % were 25 years old.

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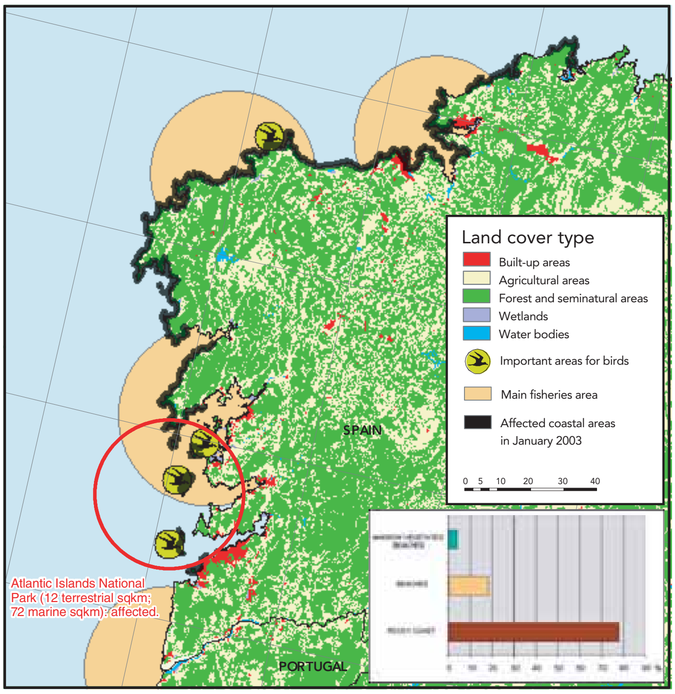
(5) Based on information from EU-15, Accession and candidate countries, EFTA countries, Monaco, Andorra, Croatia, Serbia and Montenegro and Albania.

The *Prestige* tanker accident and its environmental consequences, 2002

On 13 November 2002 the Bahamian-flag tanker *Prestige* ran into trouble during a storm 34 km off Cape Finisterre and began to leak its cargo of 77 000 tonnes of oil. After drifting for six days along the coast, the tanker broke in half about 225 kilometres off shore, having spilled about 11 000 tonnes of oil. The prow sank to a depth of 3 820 m, while the stern sank some kilometres away to a depth of 3 545 m.

Impact of *Prestige* accident on the coastal environment (15 December 2002)



Source: EEA ETC/TE, 2003.

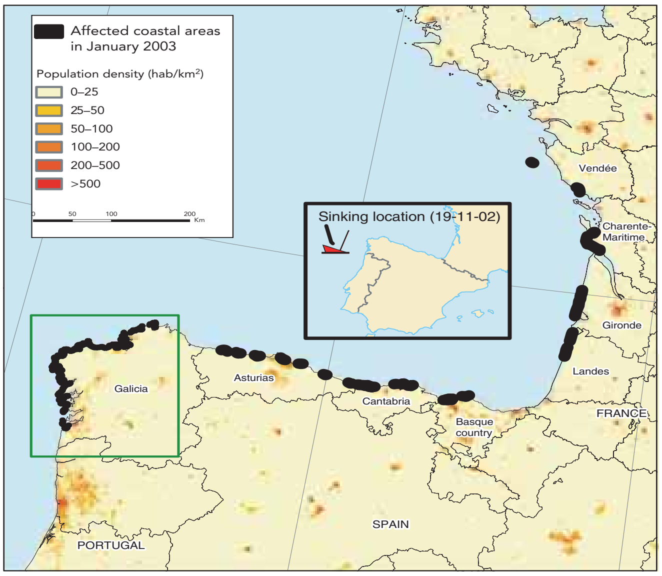
Over 100 tonnes of oil continued to escape from the wreck daily until January 2003, when the French submarine *Nautile* reduced the flow to less than two tonnes/day by patching up most of the holes. By then, about half of the original load had been spilled; about 37 500 tonnes remained in the tanks.

A survey of the wreck by Repsol YPF at the end of August 2003 revealed that only 13 800 tonnes remained. This meant that over 23 000 more tonnes of oil had escaped and would reach the coast someday. An attempt to retrieve the remaining oil is planned but will be one of the most difficult ever attempted because of the wreck's depth.

The oil transported was a heavy oil distillation product with a high sulphur content. Its degradation period is between two and three years on the water surface and much longer on the sea bottom. Some of the oil compounds can be oxidised (especially in summer) and become more soluble and toxic. Today, most of the beaches appear to be clean but, in some cases, oil can be found under the sand, occasionally showing more than one layer of oil with sand layers in between.

Several hundred kilometres of coastline were coated in oil sludge by the disaster, especially Galicia but also Asturias, Cantabria and the Basque country in Spain as well as several departments in western France (see the two maps, the first one showing the geographical extent of the pollution and the second focusing on Galicia).

Coastline affected by *Prestige* oil spills (7 January 2003)



Source: EEA-ETC/TE, 2003 (based on Le-Cedre and TERRIS).

Among the direct environmental impacts, the most noticeable one was bird mortality. By February 2003, more than 20 000 birds (over 75 % of them dead) from 71 different species had been collected. Based on these figures, a total death toll of 100 000–200 000 marine birds can be estimated, given that only 10–20 % of the birds affected by oil spills are found (SEO-Birdlife).

The Guillemot (*Uria aalge*) was the species worst hit (see picture), with more than 11 000 birds found dead. Some marine fauna and flora also died, the sensitive species attached to the ocean floor being particularly affected. Although not visible, damage to the sea bottom is worse than damage to the beaches as it plays a more functional role within the marine environment. Information on the area affected is not yet available, however.

Guillemot (*Uria aalge*)

Source: Carlos Sánchez (SEO/BirdLife).

Many coastal ecosystems (dunes, sand and pebble beaches, cliffs, etc) were damaged. More than 1 000 beaches, in Spain alone, were covered by oil tides, of which more than 20 % remain affected. Thanks to an intensive effort, about a third of the polluted rocky areas of Galicia have been cleaned. The coastal ecosystems affected include some specially protected areas, such as the Atlantic Islands Natural Park (see map). Half of the beaches in the park are still polluted. Divers have cleaned some parts of the sea bottom, but the area to be cleaned is huge. Due to the pollution some economic activities such as fishing or shell fishing were stopped immediately.

The indirect environmental impacts are more difficult to assess. The pollution has created a huge amount of waste. It is estimated that each tonne of collected oil generates 10 tonnes of waste products. Thus, the amount of waste produced so far could be about 300 000 tonnes. In addition, it is possible that, in some parts of the coast, the effect on some areas may lead to a complete disappearance of a certain habitat or the extinction of some species. In the short and medium term, a reduction of marine productivity is very likely. Many indirect impacts also result from the cleaning operations. Opening new paths to gain access to polluted areas, or aggressive cleaning practices on fragile ecosystems, such as dune systems or cliff rocks, may in some cases be more damaging than beneficial. Finally, there is also the severe economic impact of the pollution and cleaning operation on sectors such as fishing, shell fishing and tourism.

To sum up, as of autumn 2003 it was still too early to assess the full consequences of the *Prestige* accident or to estimate when the damaged ecosystems will recover. In the next three years, 18 million euro will be spent on several studies to measure the environmental and socio-economic impacts of the spill off the Galician coast. Most of the impacts were similar to the *Erika* tanker accident in December 1999, although the 'black tide' caused by *Erika* killed about three times more birds. On the other hand, the *Erika* tanker sank to a depth of only 120 m and it was quite easy to recover the remaining oil, while the *Prestige* is still a kind of environmental time-bomb, lying on the ocean floor with thousands of tonnes inside. According to a study of the aftermath of an accident that occurred in Buzzards Bay, Massachusetts, in September 1969, the effects of oil spills could be indefinite. Although many of the less heavily contaminated areas of Buzzards Bay showed little trace of oil after 10 years, oil persisted in high concentrations in some marsh sediments more than 33 years after the spill.

Faced with the often devastating consequences of oil spills, countries have steadily tightened security measures, particularly after major disasters. For instance, since 1993 all new oil tankers must be provided with double hulls, which help prevent the release of oil in case of accident, and the maximum useful lifetime of any tanker is fixed at 30 years. However, this rule does not apply to ships, such as the *Erika*, that are smaller than 20 000 tonnes.

Over the year following the *Erika* accident, the European Commission proposed two packages of legislative measures designed to combat flags of convenience and increase protection against the risks of accidental oil spills. Most of these have since become EU law. The measures include tightening checks on oil tankers visiting EU ports, establishing a European Maritime Safety Agency and banning single-hull tankers (such as the *Erika* but also the *Prestige*) from EU waters by 2015, 11 years earlier than previously foreseen. Since the *Prestige* accident the Commission has proposed bringing this deadline forward again, to 2010, and banning tankers posing the greatest risk, including those similar to the *Erika* and *Prestige*, with immediate effect.

The Commission's post-*Erika* proposals also included creating a European indemnity fund in favour of the victims of oil spills. This initiative has been taken up at the international level with a decision in May 2003 to set up a supplementary fund that will raise the indemnity ceiling beyond that of FIPOL (International Fund for Compensation for Oil Pollution Damage), currently 200 million euros, up to one billion.

References

‘Comité Científico Asesor Hundimiento del Prestige 2003’: several reports. http://www.ccaprestige.es.

CSIC: ‘Programa Científico coordinado por el CSIC para el seguimiento y la evaluación de las consecuencias del vertido del *Prestige*’. http://csicprestige.iim.csic.es.

EEA, 2002: *Accidental oil tanker spills.* Indicator fact sheet, Copenhagen: European Environment Agency. (last revised July 2002).

ETC/TE. http://terrestrial.eionet.eu.int/en_Prestige.

Greenpeace, 2003: ‘El *Prestige* seis meses después’ and other reports

http://www.greenpeace.es/gp2/petroleo/petroleo7.htm/.

IFEN, 2001: ‘*Erika*: éléments d’évaluation des dommages’. *Les données de l’environnement*, num. 68. August.

International Tanker Owners Pollution Federation Limited (ITOPF), 2003: Effects of marine oil spills. Available at http://www.itopf.com/effects.html.

‘La Voz de Galicia’ (Galician newspaper): http://www.lavozdegalicia.es/inicio.

National Geographic, 2002. http://news.nationalgeographic.com/news/2002/11/1122_021122_OilSpill.html.

Nature, 2003: Spanish plan oil-raising scheme. http://www.nature.com/nsu/030407/030407-5.html#

SEO/Birdlife, 2003: The *disaster of the Prestige oil tanker and its impact on seabirds.* http://www.seo.org/2002/prestige/report_2003-02-20.asp; http://www.seo.org/2003/araocomun/.

WWF, 2003: *The Prestige catastrophe.* http://www.panda.org/news_facts/crisis/spain_oil_spill/.

Useful links

Title: ITOPF
URL: http://www.itopf.com

Title: Concawe
URL: http://www.concawe.be

Title: Helcom The Helsinki Commission
URL: http://www.helcom.fi

Title: Regional marine pollution emergency response centre for the Mediterranean Sea (REMPEC).
URL: http://www.rempec.org/oil_traffic.html.

Industrial accidents

Type of technological accident	Date of the event (1998–2002)	Location	Impact
Industrial fire	April 1999	Bellmullet (Ireland)	700 people evacuated because of toxic fumes.
Explosion at fireworks warehouse	May 2000	Enschede (the Netherlands)	More than 20 people killed and 500 houses destroyed.
Industrial explosion	May 2001	Ludwigshafen (Germany)	130 people injured, including 50 children.
Explosion at fertiliser plant	September 2001	Toulouse (France)	30 people killed and more than 2 000 injured, more than 3 000 buildings damaged or destroyed.

Source: EM-DAT, 2003.

Fires or explosions account for half of all industrial accidents recorded in Europe over the past two decades. They are also the most dangerous type of industrial accident.

The worst industrial accident between 1998 and 2002 was the explosion at an ammonium nitrate fertiliser plant in the French city of Toulouse in September 2001 (see case study). However, the heaviest toll in human lives over the period was taken by accidents at fireworks facilities.

The most serious of these was in May 2000, when 100 tonnes of fireworks exploded at a warehouse in the middle of a low-income neighbourhood in the Dutch town of Enschede. The blast killed more than 20 people, destroyed 500 houses and left 2 000 people homeless. The same month five people were killed and 18 injured in a fire and explosion at a fireworks factory in Rafelcofer in Spain. In August 2001, an explosion at a fireworks plant in Caldelas, Portugal, killed five people and injured another.

The impact of industrial accidents can vary widely depending on the intensity and persistence of any hazardous substances involved. The geographical and temporal impact of accidents involving fires and explosions alone tends to be relatively limited but can be greatly magnified if, in a ‘domino effect’, they result in toxic substances being released to air, water or soil, as happened in the Toulouse disaster.

Protecting the local population becomes the overriding immediate concern in such cases. For example, in June 1999 a toxic cloud caused by an explosion at an agrochemical plant in the German town of Wuppertal intoxicated 90 people. In January 2002, a cloud of toxic gas from a fire at a fertiliser factory in Murcia (Spain) led authorities to require more than 170 000 people to stay indoors.

The AZF catastrophe highlights the limits of existing urbanisation control tools and the need for revising the legal and organisational mechanisms for controlling urbanisation around industrial sites in certain areas. This would also go some way towards satisfying demands for dialogue and participation from the local actors concerned about industrial risks.

In 1998, the polluted water used to extinguish a fire in a pharmaceutical complex near Turin killed all the river life in the vicinity of the plant.

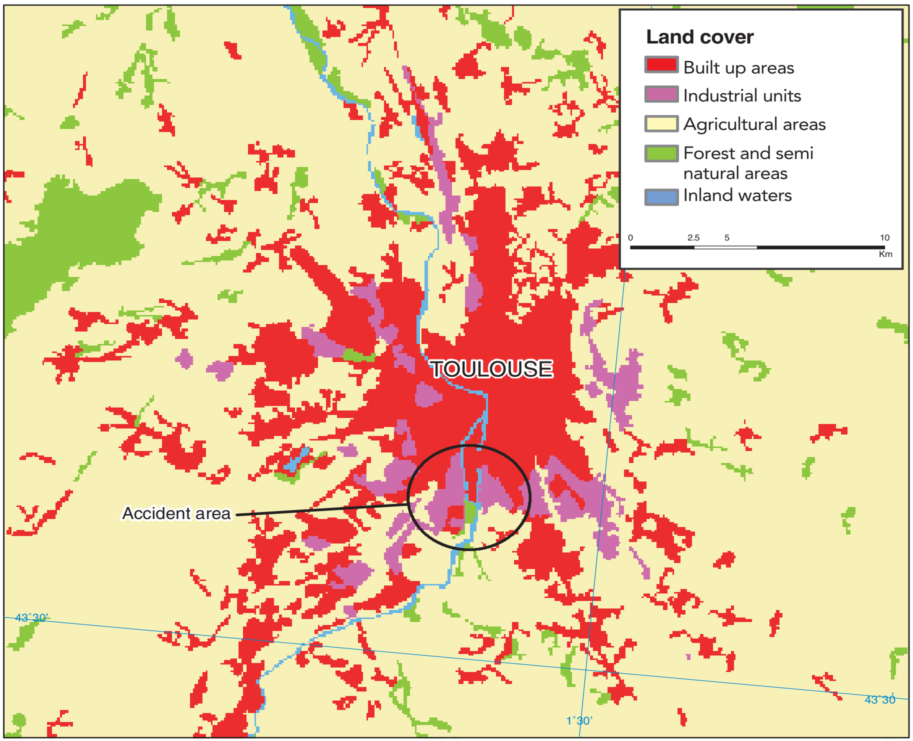
Several of the industrial accidents over the 1998–2002 period had major environmental effects. Airborne toxic pollutants can be very damaging for flora and fauna, but the strongest environmental impacts are seen when toxic substances are released into rivers and other watercourses, with lethal consequences for aquatic ecosystems and especially for fish. The impacts can be transboundary if international rivers or lakes are affected.

In May 1998, an accidental spill of about 30 tonnes of insecticide from an agrochemical factory in Hungary killed an estimated 200 000 fish in the Danube, including the entire eel population in a 400-km stretch as well as all invertebrates living on the river bed (zoobenthos) over about 15 km. It also forced the temporary suspension of the water supply to more than 20 000 people. Despite this damage, one year after the spill the same species were again present in the river,

Fertiliser factory explosion in Toulouse, 2001

On 21 September 2001, France suffered its most serious industrial accident of the past 20 years. A huge explosion ripped through the AZF (Azote de France) fertiliser factory in an industrial zone on the outskirts of Toulouse in south-west France. It is one of 1 250 French factories classified as high-risk under the European Union's Seveso directive.

Location of the Toulouse accident



Source: EEA-ETC/TE, 2003.

The blast had a magnitude equivalent to an earthquake of 3.2 on the Richter scale and created a 50-metre diameter crater. It was felt as far away as Nice, about 500 km from Toulouse. Twenty-two people were killed and more than 2 400 injured (IFEN, 2002). More than 350 people were in the plant at the time. The blast caused very considerable damage in Toulouse, particularly the southern districts. Some 2 500 houses were damaged, as well as other buildings including hospitals, schools and university buildings. Electricity supplies and telephone lines were cut. Civil aviation and industrial activity in the entire zone were immediately suspended temporarily.

The explosion occurred in a warehouse in which 300 tonnes of obsolete ammonium nitrate products were stored. The warehouse did not conform to current regulations. The site of the AZF factory housed a total of 6 000 tonnes of solid ammonium nitrate, as well as other dangerous substances (including 6 300 tonnes of liquefied ammonia, 100 tonnes of liquefied chlorine and 2 500 tonnes of methanol).

The blast produced a red cloud. It also caused local pollution of the Garonne River, where unusually high concentrations of ammonium and organic matter were measured. Total economic losses from the disaster are estimated (end of 2001) at between 900 million and 1.2 billion euro (Prefecture of Haute-Garonne).

The accident reopened debate on the location of such dangerous sites near very densely populated areas (particularly in the Rhone valley south of Lyon, the Seine estuary between Rouen and Le Havre, Dunkerque

though in reduced numbers. Also in 1998, water that became chemically polluted when used to extinguish a fire in a pharmaceutical complex near the Italian city of Turin reached the Chisola River and killed all river life in the vicinity of the plant (BARPI, 2003).

The prevention and management of major industrial accidents in the European Union is regulated by the so-called 'Seveso' directives, named after the Italian town where a chemical plant accident in 1976 released a cloud of poison gas containing dioxin that contaminated a large area and affected as many as 2 000 people.

In response to the Enschede and Toulouse accidents the EU has agreed to tighten the Seveso II directive's rules on explosives and pyrotechnic substances as well as ammonium nitrate. Other changes include strengthening the directive's provisions on land-use planning and requiring industrial operators to produce risk maps showing areas that

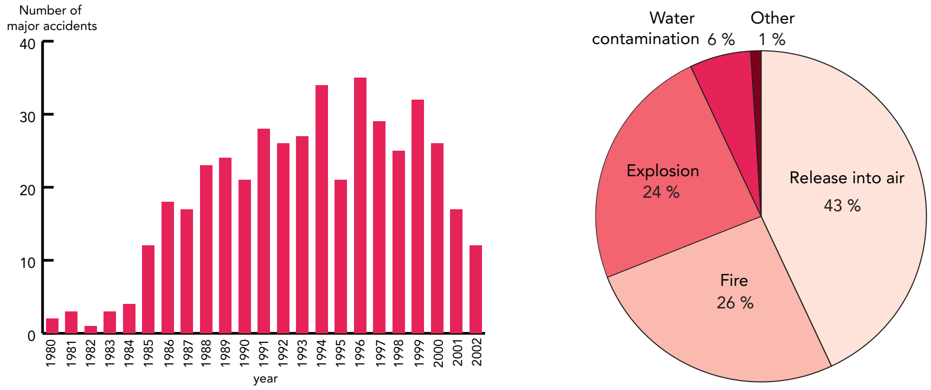


Figure 5

A) Major technological accidents reported (1980–2002)

B) Distribution of MARS technological accidents by type (1980–2002)

Note: Coverage for the years 1980–1983 is not complete. Figures until 2000 are for EU Member States (EU-9 from 1980, EU-10 from 1981, EU-12 from 1985 and EU-15 since 1995). Figures from 2001 onwards are for European OECD member countries (6).

Source: Major accident reporting system (MARS) managed by the Major Accident Hazards Bureau (MAHB).

Note: Release refers to the leakage of any dangerous substance from its container to the environment (air, water or soil).

Source: Major accident reporting system (MARS) managed by the Major Accident Hazards Bureau (MAHB).

could be affected by a major accident. The revised directive also covers more carcinogenic substances. Current discussions on reforming the regulation of chemical products in Europe may also lead to the reduction or elimination of certain dangerous substances from industrial sites.

Since 1984, industrial accidents as defined by the Seveso directives are recorded systematically in the 'Major accident reporting system' (MARS) (7) database. MARS contains information about accident characteristics, emergency measures taken and lessons learnt to improve prevention for the future. In 2003, MARS held information on more than 450 major accidents (8) in the European Union, offering important insights into their causes and possible management strategies to reduce their occurrence. The number of major technological accidents recorded by the MARS database shows a steady increase from 1984 to 1996, the year with the highest number of accidents reported. A relative decline is observed until 2002 (see Figure 5 A).

Figure 5 B shows that 50 % of industrial accidents involve fires or explosions. Just under half involve the release hazardous substances into the air, but water pollution occurs in only 6 % of accidents. A causal analysis has found that mechanical failure is the main cause of industrial accidents, followed by human, especially organisational, factors.

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(6) European OECD member countries are EU-15, Czech Republic, Hungary, Iceland, Norway, Poland, Switzerland and Turkey.

(7) MARS is a European Commission initiative operated by the Major Accident Hazards Bureau of the Joint Research Centre in Ispra (Italy).

(8) According to the Seveso II directive, the term 'major accident' refers to an occurrence such as a major emission, fire or explosion resulting from uncontrolled development in the course of the operation of any establishment covered by the directive, and leading to serious danger to human health and/or the environment, immediate or delayed, inside or outside the establishment, and involving one or more dangerous substances.

References

BARPI (Bureau d'Analyse des Risques et Pollutions Industrielles), 2003: *Données sur accidents industriels.* Paris: Ministère de l'aménagement du territoire et de l'environnement (http://aria.environnement.gouv.fr./barpinews).

EEA, 2003: *Europe's environment: the third assessment report* (Environmental assessment report No 10). Copenhagen: European Environment Agency.

Institut Français de l'Environnement, 2002: *L'environnement en France*. 2002 édition. Paris: La Découverte.

United Nations Environment Programme: Division of technology, industry and economics (DTIE). http://www.uneptie.org/pc/apell/disasters/toulouse/home.html.

Toxic spills from mining activities

Type of technological accident	Date of the event (1998–2002)	Location	Impact
Chemical spill caused by a dam failure at Aznalcóllar	April 1998	Guadiamar river, Doñana National Park (Spain)	Enormous environmental impact: 3 600 hectares of cropland destroyed, 12 tonnes of dead fish collected.
Chemical spill caused by a dam failure at Baia Mare	January 2000	Lapus river (Romania)	About 100 000 m^3 of contaminated water spilled. Major damage to the environment.

Source: EM-DAT, 2003.

Toxic pollution from mining activities is covered separately from other industrial accidents here in particular because of two major mining-related events between 1998 and 2002 that highlighted the very severe environmental impacts and huge economic costs they can have. The accidents occurred near the Doñana National Park in south-western Spain in April 1998 and in the Baia Mare region of northern Romania in January 2000 (see case studies). They figure among the worst of all environmental disasters to occur in the 1998–2002 period. Less serious accidents involving mining waste also took place elsewhere in Spain and in Sweden (EEA, 2003).

The Doñana and Baia Mare accidents both involved the breach or collapse of dams that held back storage ponds containing large quantities of water heavily contaminated by hazardous substances. The environmental impact was high because the polluted water reached rivers, spreading the contamination downstream and killing aquatic life in its path. The Baia Mare accident in particular shows how devastating and geographically extensive the effects of such accidents can be for river wildlife.

The sudden release of a large amount of contaminated water can also cause flooding that spreads the pollution. This happened in the Doñana accident, contaminating the soil and vegetation of the floodplain. More than seven million tonnes of toxic sludge had to be removed from the Guadiamar river flood plain, requiring the continuous operation of several hundred lorries for more than four months after the accident.

The cost of cleaning up the polluted area was estimated at around 100 million euro. In addition, compensation had to be paid to farmers — through land purchases by the regional government of Andalusia, among other measures — for the more than 3 600 hectares of cereals, pastures and orchards lost (Saurí, Domingo and Romero, 2003). The heavy economic impact mining waste-related accidents can have is further illustrated by the Baia Mare disaster, whose indirect economic costs alone totalled hundreds of millions of euro.

In the Doñana accident, more than seven million tonnes of toxic sludge had to be removed from the river floodplain over a four month period.

The Baia Mare spill, 2000

On 30 January 2000, almost 100 000 m^3 of water polluted with high cyanide concentrations spilled out through a 25 metre break in the dam of a waste (or 'tailings') sedimentation pond at the mining company SC AURUL SA in the region of Baia Mare in northwestern Romania. It was the beginning of one of Europe's worst transboundary pollution incidents in recent years. The contaminated water flowed into an adjoining area of around 20 hectares of agricultural land. Through drainage systems it reached the Lapus River and from there the Somes/Szamos, Tisza and Danube rivers before eventually reaching the Black Sea (see map).

The ecosystems of the Szamos, Tisza and Danube were damaged over more than 1 000 kilometres in Romania, Hungary and Serbia and Montenegro. The high cyanide concentrations killed hundreds of tonnes of fish (38 different fish species were identified). All other forms of life, including fish-eating birds, gulls, black cormorants, mute swans, foxes, roe deer, pheasants, pigeons and hares, were wiped out over hundreds of kilometres of downstream rivers in the Danube basin.

The pollution also had serious social and economic impacts on the population in the area affected by the disaster. The drinking water supply was interrupted in 24 locations, affecting over 2.5 million people. Eight drinking water wells in Bozinta Mare village were polluted.

Spread of the cyanide spill from Baia Mare. Cyanide concentration values.

	Measurement place:	Date:	Max. concentration:	
1.	Szamos at Csenger	01.02.	32.6 mg/l	cyanide
2.	Tisza at Lonya	03.02	13.5 mg/l	cyanide
3.	Tisza at Tiszalök	05.02	3.7 mg/l	cyanide
4.	Tisza at Kisköre	08.02	3.8 mg/l	cyanide
5.	Tisza at Szolnok	09.02	3.2 mg/l	cyanide
6.	Tisza at Tape	11.02	2.2 mg/l	cyanide
7.	Tisza at Tiszasziget	11.02	1.49 mg/l	cyanide

Sanitary level: 0.1 mg/l cyanide

Source: Ministry for Environmental Protection (Hungary).

Fishing and agriculture, both primary economic activities, were completely destroyed in the spillage area and its surroundings and badly damaged in the rest of the waterways affected. Industrial production was reduced or stopped, as was tourism activity. The losses totalled hundreds of millions of euro.

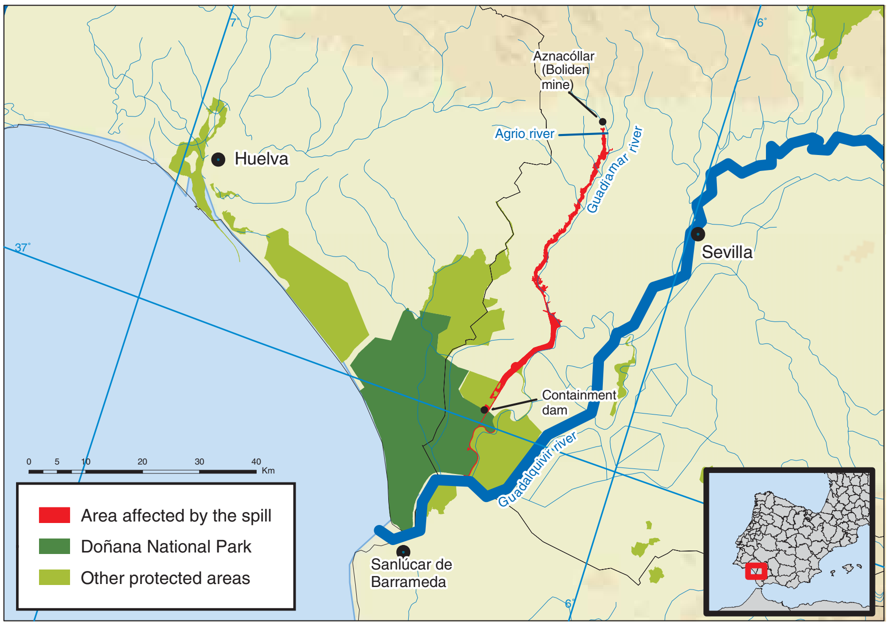
Experts predicted at the time that it would take at least five years for life to return to the rivers. Today, nearly four years later, the ecological rehabilitation of the water is almost complete, but the river bed is still contaminated and will need several more years to recover some of the species that lived there before the accident.

The Doñana spill, April 1998, and its consequences three years later

The Doñana lowlands are located in the Guadalquivir river floodplain downstream from Seville in south-west Spain. The Doñana National Park is a UNESCO-MAB (Man and the Biosphere) reserve, a Ramsar wetlands convention site and a Natural World Heritage Site. It constitutes the largest wetland reserve in southern Europe, serving as home to 80 % of the continent's migratory waterfowl. The park is also notable for the great diversity of its biotopes, especially lagoons, marshlands, fixed and mobile dunes and scrub woodland.

On 25 April 1998, the dam storing waste water from mining operations by a Spanish subsidiary of the Canadian-Swedish Boliden company in Aznalcóllar breached and spilled around four million cubic metres of acid waters, as well as two million cubic metres of toxic mud, into the fluvial system of the Agrio and Guadiamar rivers. These rivers are part of the hydrological network of the Doñana National Park (see map). The mine and the wastewater reservoir had been the subject of legal complaints from conservation organisations.

Location of Doñana toxic spill



Source: EEA-ETC/TE, 2003 (based on data from Consejería de Medio Ambiente, Junta de Andalucía)

The toxic flood inundated about 5 000 hectares of land near the watercourses (60 % crops and fields, 40 % pastures and river vegetation). While the mud accumulated in the first 40 km of the river, the acid water flowed 20 km further downstream. It was stopped by an emergency containment dam just before entering the National Park and then redirected to the Guadalquivir river. However, 98 hectares of the National Park were directly affected (0.19 % of its total area).

The immediate consequences of the catastrophe were the practical disappearance of aquatic life over the first 40 km of the spill, where about 30 tonnes of dead fish were collected (Junta de Aldalucía). Moreover, orchards, cotton plantations and rice paddies were covered in sulphurous mud laden with copper, lead, silver and zinc salts, preventing their further agricultural use. Villagers were warned not to drink water from wells, and cattle and sheep were moved from the area. Fishing was forbidden on the Atlantic coast near the Guadalquivir.

Overflow of highly contaminated slurries due to the rupture of the dam at Aznalcóllar (Spain), near Doñana National Park, 26 April 1998

Source: Consejería de Medio Ambiente, Junta de Andalucía.

Immediately after the disaster, work began to remove the toxic mud using heavy machinery. A research coordination office was assigned to monitor the ecological effects of the accident until 2001. Some of the environmental consequences three years after the event are summarised below.

Starting from a high concentration due to the pollution, a trend towards lower heavy metals levels in living organisms was noted, as well as a moderate recovery of fish and bird populations. Nevertheless, the concentrations of heavy metals remained high in many cases, such as the Red swamp crayfish (*Procambarus clarckii*) or the Common frog (*Rana perezi*). In some cases, the high concentrations resulted in hormonal disruptions and genotoxic damage, as in the case of Storks (*Cicconia cicconia*) and Red kite (*Milvus milvus*), where some Chicks presented beak malformations.

The Algerian mouse communities (*Mus spretus*) showed both genetic and physiological damage. The Eurasian otter (*Lutra lutra*) had successfully re-colonised the Guadiamar river but had been feeding on red swamp crayfish which might endanger its health.

In some areas within the Doñana National Park, high concentrations of arsenic and lead were found in plants that served as basic food for a number of birds. Concern remains over the implications for waterfowl dwelling in the park. The soil was also highly affected but to varying degrees, depending on its composition. In some cases, the soil acted as a barrier preventing the acid waters from reaching surface and ground waters. However, high concentrations of heavy metals might remain in the soil for many years.

The positive side of the story is that the affected area has since been officially declared a legally protected 'green corridor', in which industrial activity is prohibited, connecting the Doñana National Park with other important natural areas north of Seville (Sierra Morena).

Area affected by the spill: just after the accident and nine months later

Note: Aerial photos of the area affected: left, just after the spill (April 1998; in black, the toxic mud) and right, nine months after the spill with some cleaning tasks undertaken (January 1999).
Source: Consejería de Medio Ambiente, Junta de Andalucía.

'Seveso' provisions will be mandatory for mining and other extractive industries.

The disasters at Doñana and, more particularly, at Baia Mare have spurred a number of initiatives to prevent further accidents involving hazardous mining wastes. At EU level the most important of these so far is agreement on a revision of the 'Seveso II' directive on control of major accident hazards that, among other things, will apply the directive's provisions to certain mining activities, including tailings management facilities, involving dangerous substances (see also previous section). In addition, the European Commission has proposed a directive regulating the management of waste from extractive industries. Thirdly, work is also under way, within the framework of the IPPC (integrated pollution prevention and control) directive, to develop a Best Available Technology Reference Document (BREF) for tailings management facilities. For its part, the United Nations Economic Commission for Europe (UN/ECE) has developed a protocol on civil liability and compensation for damage to transboundary watercourses caused by hazardous substances. The protocol was signed during the pan-European conference of environment ministers in Kiev in May 2003 (^{9}) and, once in force, will become one of the most important pieces of European environmental law on transboundary pollution issues.

References

Aguilar, J., Dorronsoro, C., Fernández, E., Fernández, J., García, I., Martín, F., Ortiz, I., Simón, M., 2000: *El desastre ecológico de Aznalcóllar.* Universidad de Granada. http://edafologia.ugr.es/donana/aznal.htm.

Bravo M.J.B., Casas J., Gallo A., 1998. 'Doñana, en el purgatorio'. *Ecosistemas* No 24/25. Multimedia Ambiental, S.L. Asociación Española de Ecología Terrestre.

'Consejo Superior de Investigaciones Científicas', Spanish Research Council. http://www.csic.es/hispano/coto/infor13/infor13.htm.

Department of Public Health, Maramures District: *The ecological accident,* AURUL Society, Baia Mare, Romania.

EEA, 2003: *Europe's environment: the third assessment report* (Environmental assessment report No 10). Copenhagen: European Environment Agency.

Fabiani, J.-L. and Theys, J. (ed.), 1987: *La societé vulnerable.* Paris: Presses de l'école normale supérieure. (Chapter 1).

Greenpeace. http://www.greenpeace.se/norway/english/3media/pr/990422.htm.

Jiménez Luque, Begoña. *Evaluación de contaminantes químicos en seres vivos el vertido minero de Aznalcóllar.* Programa de seguimiento de seres vivos en el Parque Nacional de Doñana. Departamento de Análisis Instrumental y Química Ambiental, IQO-CSIC.

Junta de Andalucía. http://www.juntadeandalucia.es/medioambiente/pdf_donana/h12_flora_y_fauna.pdf.

Media Data Bank, MTI (Hungary).

Romanian mine accidents. Environmental disasters in central Europe. http://www.zpok.hu/cyanide/baiamare.

Domingo, V., Romero, A. and Saurí, D., 2003: 'Trust and community building in the Doñana toxic spill disaster'. *Journal of Risk Research,* 6(2), pp. 145–162.

UNESCO http://whc.unesco.org/archive/repcomx99.htm#sc685.

Waste magazine. http://www.ideal.es/waste/vertido.html.

WWF 2002: *The ecological effects of mining spills in the Tisza river system in 2000.* Vienna: WWF.

Useful links

Title: WWF, Europe Programme
URL: http://www.panda.org/about_wwf/where_we_work/europe/what_we_do/toxics.cfm.

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(9) The 5th Ministerial Environment for Europe Conference (under the framework of the United Nations Economic Council for Europe) took place in Kiev from 21 to 23 May, 2003. For the text of the protocol, see http://www.unece.org/env/civil-liability/protocol.html

Conclusions

Over the 1998–2002 period a large number of major natural disasters and technological accidents were reported across Europe. Collectively, and in many cases individually, these had very considerable human, economic, and environmental impacts, many of which are covered in this report.

Natural disasters and technological accidents are not always singular or isolated events. The examples in this report show that they can occur in complex combinations and/or in rapid succession, thereby triggering multiple effects (for example, forest fires that cause soil erosion or heavy rainfall that causes the breach of dams holding back hazardous wastes). Future policies should consider an integrated approach to addressing these issues. More integrated policies, in particular regarding land use planning but also in sectors that are vulnerable to disasters and accidents, such as transport and industry, could also help to reduce the socio-economic and environmental costs of such events.

The environmental impacts of natural disasters and technological accidents are often difficult to assess. In some cases environmental impacts are not apparent immediately after an event. The impacts may be considerable in the short term but disappear over time due to the ability of some natural systems to recover relatively quickly. Further research is needed in this area and to help implement viable restoration measures.

Some of the extreme events covered in this report had significant transboundary impacts. EU enlargement provides an opportunity to strengthen cooperation between European countries in response to such events and to coordinate prevention, remediation and public information measures across a much larger area of Europe.

A planned European Commission communication on a common EU approach to natural and technological risks will represent the first step towards implementing a common and harmonised view on mapping hazards and risk prevention in an enlarged Europe. This report complements the policy process by providing an overview of major recent events with the aid of maps. The European Environment Agency will continue work in this area in support of EU and other international initiatives to promote a common approach to managing such risks.