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SHORT COMMUNICATION

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European Atlantic: the hottest oil spill hotspot worldwide

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Abstract Oil spills caused by maritime transport of petroleum products are still an important source of ocean pollution, especially in main production areas and along major transport routes. We here provide a historical and geographic analysis of the major oil spills (>700 t) since 1960. Spills were recorded from several key marine ecosystems and marine biodiversity hotspots. The past four decades have been characterized by an overall decrease in the number of accidents and tonnes of oil spilled in the sea, but this trend was less distinct in the European Atlantic area. Recent black tides from the *Erika* and *Prestige* vessels provided new evidence for the high risk of accidents with serious ecological impact in this area, which according to our analysis is historically the most important oil spill hotspot worldwide. The English Channel and waters around Galicia in Spain were the areas with most accidents. Maritime transport in European Atlantic waters has been predicted to continue increasing. Together with our own results this suggests that, in addition to measures for increased traffic safety, deployment of emergency capacities in the spill hotspot areas may be crucial for a sustainable conservation of sea resources and ecosystems.

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Introduction

Oil spills are one of the major causes of ocean pollution, producing ecological disasters of wide public concern (e.g., Monson et al. 2000; Serret et al. 2002). Birds (Lance et al. 2001; SEO/Birdlife 2003), sea mammals (Garrott et al. 1993; Monson et al. 2000), fish (Rice et al. 2001; Heintz et al. 2000), and several marine invertebrate species (Glegg et al. 1999; Carls et al. 2001), are among the groups most impacted by these ecological disasters, although in some black tides the whole food chain has been affected (Peterson et al. 2003). Oil spills can negatively influence the physiology, inmunology, and development of some organisms (Duffy et al. 1994; Briggs et al. 1997; Dyrynda et al. 2000; Heintz et al. 2000; Downs et al. 2002; Rotterman and Monnett 2002), but their most evident effect is usually an important decrease or disappearance of populations of marine fauna and flora within the affected area (e.g., Frost et al. 1999). The effects of crude oil on the organisms and the time needed for the recovery of ecosystems and populations are different among species, and are subject to controversy (Wiens et al. 1996; Murphy et al. 1997; Lance et al. 2001; Esler et al. 2002, Peterson et al. 2003)

Although the spills with the highest recognized ecological impacts were usually those in which the greatest volume of oil was spilled in the sea, a small quantity of oil spilled in pristine places can also negatively affect endangered species, as it has been reported from the Galapagos Islands after the sinking of *Jessica* (Wikelski et al. 2002). Linked to the damage caused to the environment are the high costs to fisheries, related industries, and tourism in the affected areas. This is especially true along the major oil tanker transport routes.

Despite overall increased tanker security, history repeated itself in northwestern Spain when the *Prestige* sank on 19 November 2002 and contaminated the Galician coastline with 60,000 t of oil. The ecological damage along about 900 km of coastline, from northern Portugal to southern France, may in part be the consequence of an ineffective initial technical management of the crisis (Serret et al. 2003). In summer 2004, some areas of the coast are still not yet fully clean and the ecological impact not yet assessed.

The disaster of the *Prestige* and the sinking of the *Erika* off the French coast in 1999 were the last large black tides on a long list of spills in European Atlantic waters. The European Commission reacted by preparing on 27 March 2003 a proposal that will completely ban single-hulled tankers from EU ports. This proposal assesses the risks of spills in European waters by quoting the *Prestige* catastrophe and aerial surveys of small-scale spills (<100 t) in the Baltic Sea (HELCOM 2003), but no comprehensive geographical oil spill statistics. The apparent lack of such a study prompted us to analyze major tanker oil spills in a geographical and historical context for the world seas. Our aim was to assess whether the apparent high incidence of tanker accidents in the European Atlantic indeed reflects a relevant trend or is merely an artifact of intense media coverage of accidents in European waters.

Materials and methods

We compiled a database (see Electronic Supplementary Material) of historical oil spills since the start of large-scale maritime transport and associated statistics, covering the period from 1960 to 2002. Our analysis considered oil spills in which the source was a vessel, generally a tanker or a barge, with a cargo of any petroleum product. Only accidental spills were regarded and acts of war were not included. Only maritime oil spills were considered and those that occurred in rivers were excluded. Because significant information was only available for large-scale spills (>700 t) we ignored smaller spills (ITOPF 2002).

Data were gathered from different sources, mainly from the Tanker Spills Database of the Environmental Technology Centre (http://www.etcentre.org) and the Oil Spill Intelligence Report newsletter. Our database was completed with data from NOAA (1992) and Yoshioka et al. (1999). Data sources were compared and in the case of discrepancies regarding the amount of petrol spilled we used the lowest of the values reported. When available, we used the coordinates provided in the different sources to georeference each oil spill on a digital world map. In most cases only approximate locations were available, which however enabled us to place spills on a Marsden Square Chart, consisting of a division of the world into grids of 10° of latitude and longitude. Seven accidents could not be reliably placed into any grid square; these were excluded from the geographical analysis but not from the global trend analysis. For each grid square, both the total number of accidents and the total amount of oil spilled were calculated. Analyses were done using ArcView GIS software. The boundaries of the Large Marine Ecosystems of the World were obtained from National Oceanic and Atmospheric Administration (http://www.noaa.org). Trend analyses were calculated using nonparametric Mann-Kendall tests from 1970 to 2002, starting with the year of the first year of accidents in the Baltic and Mediterranean seas (1970). The number of tonnes spilled per year was log-transformed for the calculations in order to normalize data distribution.

We herein use a definition of the "European Atlantic" based on Article 1 of the OSPAR convention but with reduced longitudinal ranges. The area lies north of 36° N latitude and between 13° W and 32° E longitude, excluding Baltic Sea and Mediterranean Sea east of 5° 36′ W longitude.

Results

In total, 410 large vessel oil spills of more than 700 t have occurred since 1960 and polluted the oceans with over 5.5 million tonnes of oil. The occurrence of oil spills correlates with all major crude production areas and sea transport routes (Fig. 1). The Persian gulf and Mexican gulf down to Venezuela show high spill volumes and the same happens in the major sea transport routes with ~280,000 t spilled around the southern tip of Africa and ~300,000 t in the eastern Mediterranean. Most of the spills analyzed overlap with the Large Marine Ecosystems of the World, defined by the NOAA as the most productive areas in the oceans (Fig. 1), and in zones with some of the most important and fragile coral reef ecosystems and marine biodiversity hotspots worldwide

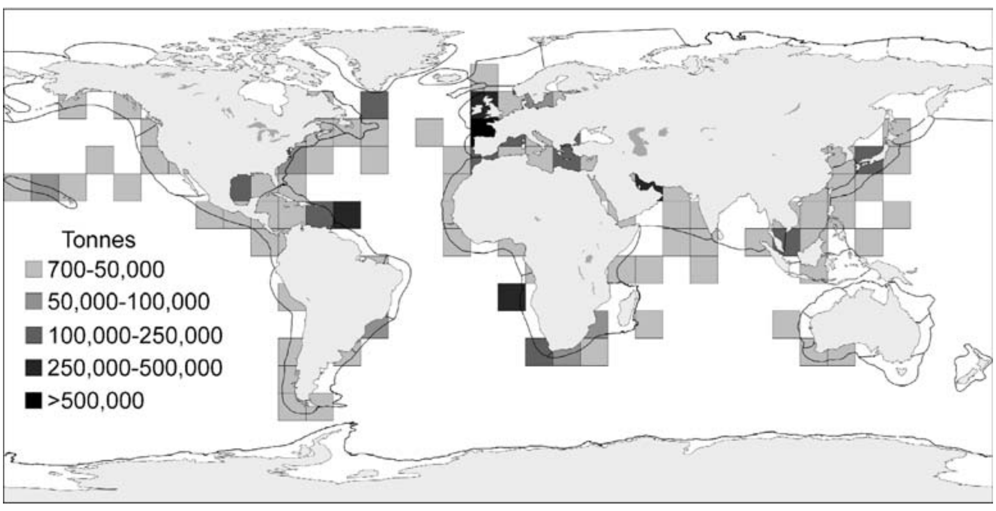

Fig. 1 Worldwide distribution of oil spilled in the seas by maritime transport from 1965 to 2002 (see Electronic Supplementary Material). The *different intensities of gray* correspond to the number of tonnes spilled per each 10° square. The *dark black line* illustrates the boundaries of the Large Marine Ecosystems of the World (http://www.noaa.org)

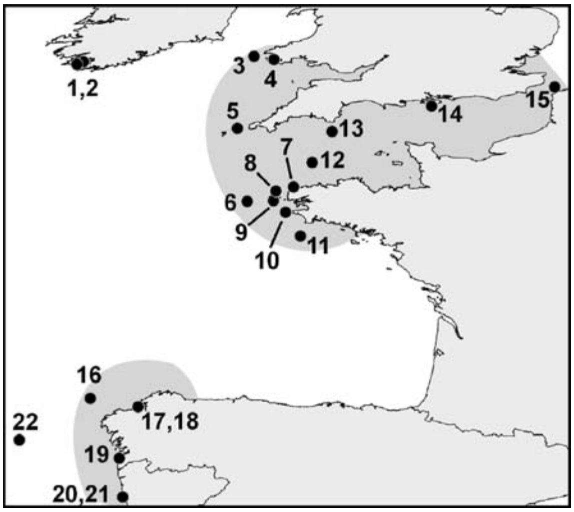

Fig. 2 Distribution of principal oil spill accidents in Atlantic European coastal waters; the English Channel and Galician waters (*shaded gray*) concentrate most of the accidents. *Numbers* indicate vessels (thousand tonnes *in brackets*): *1 Betelgeuse* (44); *2 Universe Leader* (2.2); *3 Christos Bitas* (3.7); *4 Sea Empress* (74.4); *5 Torrey Canyon* (119); *6 Gino* (41.8); *7 Amoco Cádiz* (233); *8 Olympic Bravery* (0.7); *9 Bohlen* (7); *10 Amazzone* (2); *11 Erika* (19.7); *12 Tanio* (17); *13 Mt Rose Bay* (1); *14 Pacific Glory* (3); *15 Olympic Alliance* (11.8); *16 Andros Patria* (47); *17 Urquiola* (100); *18 Aegen sea* (74); *19 Polycommander* (16); *20 Jakob Maersk* (86.7); *21 Cercal* (1); *22 Prestige* (60)

(Roberts et al. 2002). However, the European Atlantic proved to be the most important hotspot. With one-fifth of the global amounts (1,097,359 t, in the period 1960–2002), spills by maritime transport in this region were even more important than in the production areas.

Within the European Atlantic, the English Channel and the Galician coast in NW Spain were the most affected areas with 526,151 and 377,765 t, respectively (Fig. 2). Most of the European marine traffic passes through these areas, which translates into ten large accidents since 1980, with a rate of one accident every 2.3 years.

There is a clear trend in the decrease both of the number of accidents and tonnes spilled in the world seas from 1970 to 2002 (Mann-Kendall $Z=-3.78$, $P<0.001$, $n=33$ years; and $Z=-3.15$, $P<0.01$, $n=33$ respectively). This pattern coincides with previous analyses (Anderson and Labelle 2000; ITOPF 2002). The same significant decrease in the number of accidents and tonnes spilled is observed in the Mediterranean sea ($Z=-3.48$, $P<0.001$, $n=33$; $Z=-3.22$, $P<0.01$, $n=33$, respectively), but not in the Baltic sea ($Z=-1.31$, $P>0.5$, $n=33$; $Z=-1.39$, $P>0.5$, $n=33$, respectively) or in European Atlantic waters ($Z=-1.42$, $P>0.5$, $n=33$; $Z=-0.22$, $P>0.5$, $n=33$, respectively).

After a maximum in the 1970s (0.60 million t; 26 accidents) and an important decrease in the 1980s (0.06 million t; 13 accidents), in the 1990s the European Atlantic again experienced nine vessel accidents with 0.27 million t spilled. From 2000 to 2002, a single accident was responsible for the spilling of 60,000 t of oil; considering this spill, and optimistically assuming that no further accidents will occur until 2010, the amount of spillage for the present decade already exceeds that of the 1980s. In the Mediterranean the maximum number of accidents took also place in the 1970s (21), decreasing gradually to zero in the present decade; and in the Baltic, although no trends were detected, both the number of accidents (10, 1970–2002) and total tonnes spilled (85,454, 1970–2002) were very low by comparison with the Mediterranean and European Atlantic.

Discussion

Despite many efforts and obvious improvements since the 1970s, contamination by marine traffic accidents is still one of the major threats for the world seas, and oil spills are still a major part of this problem. The major routes of sea traffic cross the boundaries of the Large Marine Ecosystems and of the marine biodiversity hotspots (Roberts et al. 2002), and tanker accidents have been reported from these areas. Key ecosystems and species may be permanently damaged regardless of the size of the spill (Wikelski et al. 2002) and indirect long-term effects cannot be excluded (Peterson et al. 2003).

Regarding the European Atlantic, the *Prestige* and *Erika* disasters were the most recent large oil spills in this area. They severely contaminated some of the ecologically most important coastlines of Spain and France, which harbor key ecosystems, important fisheries and are the wintering ground for thousands of marine birds. More than 77,000 and 21,500 dead birds were recovered as a result of the *Erika* and *Prestige* oil spills, but these numbers probably represent only a fraction of the total deaths (SEO/BirdLife 2003). The decision to move the *Prestige* away from the coast increased the impact of the black tide because of its subsequent dispersion through the Iberian coast to France following dominant currents (Serret et al. 2003). The *Prestige* wreck is now at about 3,000 m depth, and in summer 2004 the Spanish government was still trying to recover the 17,000 t of oil not spilled from its tanks. The wreck is located close to the Galician Bank, a large seamount and ecologically rich zone that has recently been proposed as a Special Area of Conservation and potential Marine Protected Area under the EU Habitats Directive (Schmidt and García 2003). The spill has also heavily affected the recently founded marine-terrestrial Spanish National Park of the Atlantic Islands. Although more monitoring will be needed in order to assess the long-term environmental impact of the *Erika* and *Prestige* spills (Peterson et al. 2003), short-term negative effects have been obvious

Despite the worldwide decrease in the number of accidents and amount of oil spilled, this trend is not significant in the European Atlantic according to our analysis. The English Channel and Galician waters seem to be the areas of maximum concern. Although the levels are lower than in the 1970s, the threat has not significantly diminished. A significant decrease is observed in the Mediterranean but not in the Baltic (major European sea transport routes), although the levels in the Baltic are very low. Also, maritime traffic in the European Atlantic is likely to increase even more in the future. Figures for the European

Union assume a continued increase in trade from Baltic ports until 2017, leading to a 25% higher risk of large oil spills (HELCOM 2003). If all plans for new terminals are fulfilled, oil handling capacity will increase from 53 million t per year in 1995 to 137 million t per year (SSPA 1996). Traffic of tankers through the European oil spill hotspots is therefore likely to increase as well.

There is no doubt that increased safety of maritime transport must be one of the priorities for future long-term ocean management. Half of the accidents in the European Atlantic took place in autumn and winter and coincided with storms or bad weather that disabled oil collection (Höfer 2003; Whitfield 2003). The European Union reacted to the *Prestige* spill by urging the application of the Erika I and II packages, establishing a European Maritime Safety Agency, a Committee for the Prevention of Pollution from Ships, restricting the age of the tankers and banning single-hulled tankers. These measures can be expected to become a reality in the immediate future and will certainly have positive effects. As well as safety regulations it will be crucial to make sufficient technical means locally available, thereby allowing immediate action in the case of accidents. Local emergency plans need to be developed and clear recommendations issued for how to deal with damaged tankers. Based on the identification of oil spill hotspots, emergency capacity and ports of refuge should be deployed in the areas most at risk.

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