The Extent of Seismic Exploration Worldwide, 1994 - 2004

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ABSTRACT

The aim of this paper is to investigate the extent of seismic exploration on a global scale and how this is changing. This is explored by splitting the available data from 1994 to 2004 into 8 regions. The data are difficult to interpret because of their varying quality. We conclude that future reporting should be standardised, mandatory and transparent throughout the industry to aid our understanding of the extent of seismic surveys globally and therefore the potential impact on marine fauna.

KEYWORDS: Noise, seismic survey, USA, Commonwealth of Independent States (CIS), Middle East, Far East, Europe, Canada, Latin America, Brazil, Africa, Angola

INTRODUCTION

Seismic exploration is a technique used by the offshore oil and gas industry to investigate fossil fuel deposits below the seabed. High energy, low frequency sound, typically produced by 'air guns' is used to locate oil and gas reserves under the sea floor**.** Up to 70 air guns vent high pressure air into the ocean, which produces an air filled cavity which expands, contracts, and then expands again (McCarthy, 2004). The sound pressure wave produced is measured by an array of towed hydrophones. The peak pressure levels for industry arrays are in the 5- to 300-Hz range (Hildebrand, 2005)**.**

Globally, there are currently around 100 registered seismic survey vessels, with an estimated 15 to 20 operating at any one time (Cummings, 2005). Surveys often continue for weeks at a time. If the survey area is large, 2D seismic surveys are usually used with an array of air guns for greater accuracy. This type of survey normally fires in the range of 230-255 dB re 1µ Pa-m (McCauley, 1994). Seismic surveys are either high resolution (often 3D) producing low energy, and used in shallow water, or low resolution (usually 2D) used for deep water (MMS, 2003). Seismic guns fire every 8 to 20 seconds, although high resolution surveys can fire more frequently. Although most of the energy is directed at the sea floor some inevitably escapes to the surrounding environment, for example, see Madsen *et al*. (2006). The low frequencies at which most of the energy is concentrated (5-200 Hz) are able to travel enormous distances. For example, Nieukirk, *et al*. (2004) reported that in the North Atlantic air-guns were detected thousands of kilometers from the survey site.

Seismic exploration is a concern with regard to cetaceans and other marine life as there is mounting evidence in the scientific literature demonstrating the detrimental effects of anthropogenic undersea noise on marine mammals and other species (Simmonds *et al.,* 2006). These range from direct physical effects such as permanent or temporary hearing threshold shift (PTS or TTS), to gas bubble lesions in the liver, and behavioural effects such as displacement from preferred habitats and acoustic masking preventing communication (Dolman and Simmonds, 2006). A discussion of the mitigation of the potential effects of seismic surveys on marine mammals is provided by Weir *et al.* (2006).

The International Whaling Commission Scientific Committee has recognised increases in seismic noise as "cause for serious concern" (IWC, 2004). It also emphasised the importance of applying the precautionary

principle in addressing the issue and it made a number of specific recommendations for reducing impacts of seismic exploration. Finally, it made a commitment to return to this issue, at this meeting, in 2006.

The aim of this report is to investigate the extent of seismic exploration on a global scale by examining the available data between 1994 and 2004.

METHOD

The collection of the data used in this report was commissioned by the National Resources Defense Council (NRDC) from World Geophysical News, published by IHS Energy[1]. IHS Energy is a provider of information and advisory services to both governments and industry and maintains databases, and employs processes and technology to collect, manage and deliver an inventory of information with regards to the oil and gas industry. Data are provided to IHS on a voluntary basis from independent seismic operators and oil and gas companies.

The data available were divided into 8 regions:

- USA
- Commonwealth of Independent States (CIS)[2]
- Middle East
- Far East (including Australia and New Zealand)
- Europe
- Canada
- Latin America
- Africa

The data were separated into two categories: (i) Number of crews operating and (ii) Number of areas in which surveys had been carried out. The number of crews operating was summed to provide a total for each year and the number of different offshore areas within each region was identified for each year to show any possible trends arising over the ten year period.

The data were provided in a spreadsheet format, with offshore areas considered on a monthly basis from 1994 to 2004. Each region (e.g. Africa) was divided into areas (e.g. Algeria Offshore):

Year	Month	Region	Offshore Area	Crews
2000	11	Africa	Algeria Offshore	1

However, the scale of the geographic location of reported surveys is variable. In some instances companies have documented only to a broad general area (for example 'China offshore') or in a vague manner (e.g. unspecified 'various areas') and sometimes the location is 'undisclosed'. In other instances the location of specific bathymetric features are reported (for example 'Mississippi Canyon').

The number of 'undisclosed locations' or 'various areas' differ among regions. These had to be counted as one area due to lack of further details in the data. The number of offshore areas calculated is, therefore, the lowest estimate. In support of this, we have found that the numbers of crews in operation were greater in the 'undisclosed locations' for some regions.

We believe for this set of data that one crew approximates to one active seismic ship working for up to two weeks (NRDC pers. comm.).

[1] All original data is credited to IHS Energy and NRDC.

[2] The Commonwealth of Independent States (CIS) includes Armenia, Azerbaijan, Belarus, Georgia, Kazakhstan, Kyrgyzstan, Republic of Moldova, Russian Federation, Tajikistan, Turkmenistan, Ukraine and Uzbekistan.

Line and scatter graphs were used to document trends. Line graphs illustrate trends in the number of crews operating between 1994 and 2004, displaying a large quantity of raw data over a long time frame.

Scatter graphs with trend lines illustrate the number of areas surveyed within a particular region over time (for example how many areas had been surveyed in the region defined as Africa from 1994 to 2004). The number of areas in which surveys had been carried out was then counted for each year to show the number of areas within a region being surveyed over time.

Two case studies are presented: Brazil and Angola. These provide a focus on regions of high and increasing seismic activity. Each area has applied a different strategy for management and mitigation of noise impacts from seismic activities for the protection of cetaceans. The contrast between the two case study areas is apparent: Brazil has an effective MPA (Marine Protected Area) whereas Angola has not.

We note that data collected on a voluntary basis presents several limitations. Undoubtedly, some surveys and associated data will not have been reported, and the extent of this is unknown. There is also variability in the level of reporting within and between regions. Therefore data should be interpreted with extreme care.

RESULTS AND DISCUSSION

Results are presented in Table 1 and Figures 1-18. The extent of worldwide seismic surveys is reflected in the general patterns shown by Figures 1–2, which include all eight regions.

The data available are likely to be undersupplied. In addition to this 9.6% of the global monthly reports provided in the data are from undisclosed locations or various areas. The number of areas that have undergone surveys are therefore undoubtedly higher than the figures demonstrate (see Table 1).

United States of America

It appears that the USA has undergone a large drop in the number of crews operating due to declines in the Gulf of Mexico, but the number of areas in which surveys have been carried out has risen over the 10 year period. This could indicate oil and gas exploration is moving further a field (see Figures 3 &4).

Undisclosed locations and unspecified areas account for 20.8% of the total number of monthly reports from 1994 to 2004 – forming the largest proportion of all 8 regions. It is unlikely that the 'undisclosed locations' were one area, as there were significantly more surveys being carried out. The average number of crews operating on a monthly basis in the undisclosed locations and unspecified was 9.1, whereas in more specific locations in the USA the number of crews averaged 1.86. The actual number of areas surveyed is therefore likely to be significantly higher.

However, some areas within the US were reported with high accurately, so there is a large amount of variation in data reporting for this region. When examined globally, some of the most heavily surveyed areas are within US waters. There are already a large number of crews operating compared to other regions and the number of areas being surveyed continues to increase. Some 1,862,850 miles have been surveyed using 2D type arrays in US waters since 1968 (Dellagiarino *et al*., 2000).

There are indications that the total number of surveys and the number of areas surveyed off the US will rise over the next several years. The U.S. Minerals Management Service predicts that survey rates in the Gulf of Mexico and in the Arctic will increase into the next decade (MMS 2004, MMS 2006). In addition, the U.S. Congress has mandated the Service to undertake a comprehensive inventory of oil and gas reserves on the U.S. Outer continental shelf (Energy Policy Act of 2005, Pub. L. No. 109-58, § 357, 119 Stat. 594, 720), which may expand surveys to areas not under immediate consideration for leasing.

Commonwealth Independent States

The number of crews operating in this region has decreased over the ten-year period, but the number of areas in which surveys are being carried out has increased. No crews were reported to be operating in 1999 which could indicate reporting was not comprehensive (see Figures 5 & 6).

Undisclosed locations account for 10% of the total number of the monthly reports from 1994 to 2004. This is roughly average for the number of undisclosed locations when compared to the other regions.

Middle East
The data shows the Middle East has one of the most rapid increases in the number of areas being surveyed when compared to other regions. This increase is reflected by the number of crews operating, and the number of areas in which surveys have been carried out, which increased until 2002, and then both began to decline (see Figures 7 & 8).

The number of undisclosed locations surveyed appears much lower in 1994 than in 2003. This indicates an increase in the number of areas being surveyed in more recent years. Undisclosed locations account for 19.6% of the total number of the monthly reports from 1994 to 2004. This is a large proportion of the monthly reports and could relate to many different areas. Therefore, not only could the number of areas being surveyed be increasing more rapidly than shown, but the overall number of locations being surveyed is likely higher for the entire period.

Far East
The Far East (including Australasia) is the only region for which the data show a clear increase in both the number of crews operating and the number of areas being surveyed (see Figures 9 & 10). Again, the number of crews operating in undisclosed locations is high, where 8.1% of the total number of the monthly reports are from undisclosed locations. Unlike the USA, this trend has not increased in recent years.

There are consistently high numbers of crews operating, with the number of areas that have been surveyed from 2000 to 2004 exceeding all other regions. Australia has the highest proportion of crews operating compared to other countries in the Far East.

Europe
The data available indicates that Europe is the only area to demonstrate both a decrease in both the number of crews operating and in the number of areas in which surveys are being carried out (see Figures 11 & 12). Undisclosed locations account for 2.9% of the monthly reports, which is low when compared to other most other regions. Seismic crews are predominantly active in the North Sea.

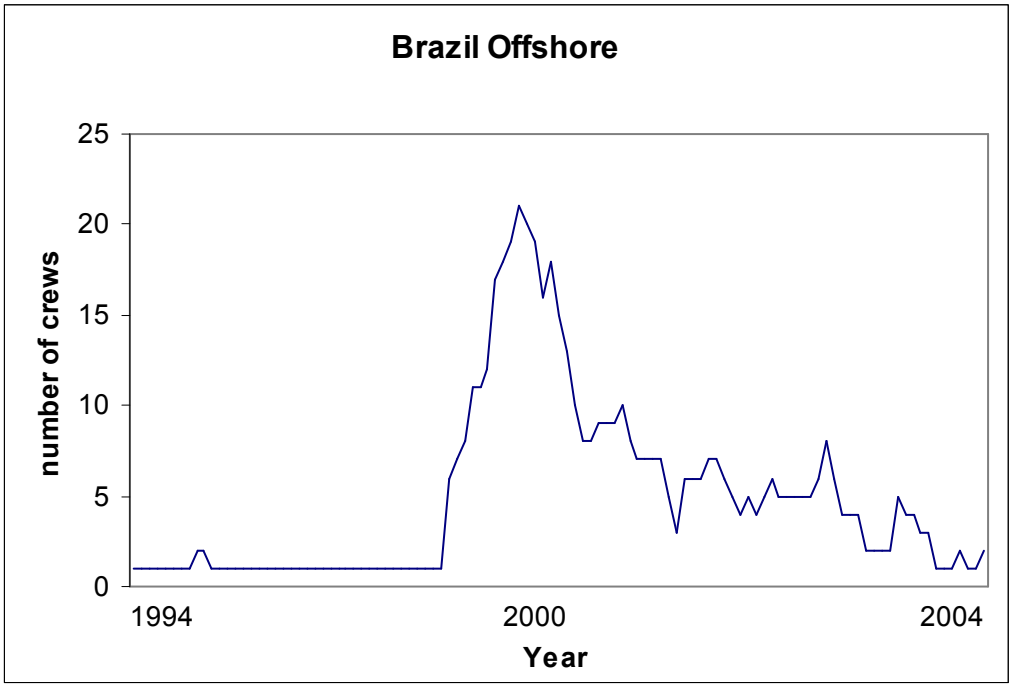
Canada
Canada has undergone a relatively small number of seismic surveys when compared to other regions. Despite a peak in 1999 and 2000 the number of crews operating, and the number of areas in which surveys were carried out in Canadian waters, has remained comparatively low (see Figure 13 & 14).

Canada is the only region to have no areas which are counted as various areas or undisclosed locations. It is also the region which, according to the data, has undergone the least exploration with low numbers of crews operating. This is a very different situation when compared to US waters with widespread oil and gas exploration; hence the two countries were not grouped together in a 'North America' region. Canada's federal and provincial governments are currently debating the lifting of a production moratorium off the coast of British Columbia. If lifted, seismic surveys off the west coast of Canada may significantly increase.

Latin America
Latin America has shown a reasonably constant amount of exploration taking place between 1994 and 2004 despite some fluctuations. Undisclosed locations account for 8.9% of the total number of the monthly reports in Latin America. Latin America has shown consistent levels of crews operating and the number of areas being surveyed (see Figures 15 &16). By far the most surveyed areas are in offshore Brazil. However, general areas such as 'Venezuela offshore' make it difficult to identify exactly where the crews are operating.

In 2000, there was a peak in the number of crews operating and the number of areas in which surveys are carried out. A decline occurs after the Brazilian government banned seismic surveys on the northeastern coast of Brazil. Further details are given in the Case Study below.

CASE STUDY: OFFSHORE BRAZIL, LATIN AMERICA



The trend of seismic activity in the waters offshore Brazil, according the available data.

Exploration and production of mineral resources is a young industry in Brazil, where licensing began in 1999. The large number of seismic surveys carried out in 2000 and 2001 was particularly high for this region.

During the 2002 breeding season an unusual stranding of 8 Humpbacks occurred in the Abrolhos bank, on the northeastern coast of Brazil. This event coincided with 3D seismic surveys occurring in the region, leading IBAMA, the Brazilian Ministry of the environment's enforcement agency, to place a moratorium on seismic surveys during the breeding season of humpback whales, *Megaptera novaeangliae,* between July and November (Engel *et al*. 2004).

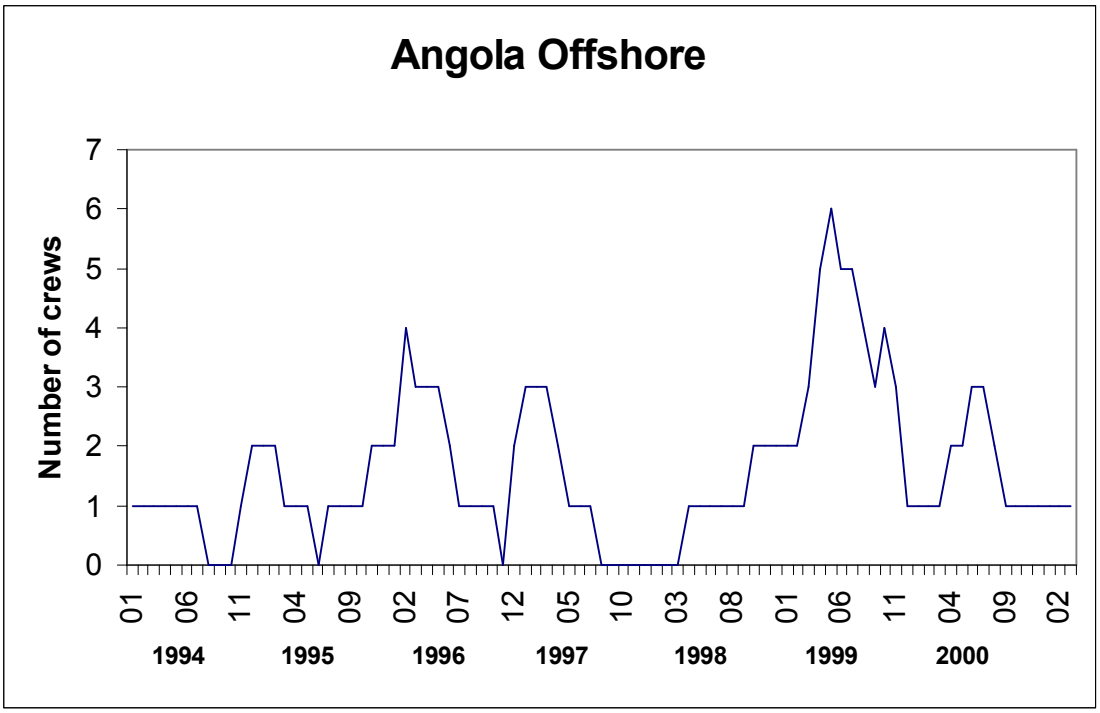
Of the 43 species of cetacean recorded in Brazil, 26 are listed as either endangered, vulnerable, conservation dependent, or data deficient. Parente and de Araújo (2005) found that cetacean diversity decreased with increased seismic surveys in the regions of northeast and southeast Brazil. This trend was demonstrated largely by the Delphinidae family. It is possible that the effects were not direct, but in response to prey depletion.

Africa

Africa demonstrates a relatively sharp increase in the number of areas surveyed over the past decade, while the number of crews operating has declined despite peaks in 1999 and 2003 (see Figures 17 & 18). Offshore areas around Angola have been subject to a large amount of seismic surveying (see case study).

In African waters, 6.5% of the total number of the monthly reports are from undisclosed locations, which is lower when compared to regions such as the USA and the Middle East. However, many of the reports simply state 'Namibia offshore' or similar. There was very little detailed reporting for this region.

CASE STUDY: OFFSHORE ANGOLA, WEST AFRICA



The trend of seismic activity in the waters offshore Angola, according the available data.

Offshore areas in the south west Atlantic off Angola have received persistent seismic surveys for 6 years between 1994 and 2000. Surveys were ongoing after 2001 but these were not reported in this data set.

The persistent seismic exploration in this region is not unique. Nigeria and South Africa, as well as an area simply given as 'West Africa Offshore' have undergone constant seismic exploration for years at a time.

We note that humpback whales are a species that return annually to traditional breeding and feeding grounds off west Africa. Angola, the African west coast and the Gulf of Guinea breeding grounds overlap with an area of increasing seismic survey activity (Weir *et al*., 2006). Yet, unlike Brazil, Angola does not have designated closed areas or a seasonal closed area to protect breeding humpback whales.

CONCLUSION AND RECOMMENDATIONS

Whilst the data have to be interpreted with care, there is apparently an increasing trend in the use of air gun arrays worldwide (despite a fall in the number of crews operating), with some significant regional variations. Meanwhile, there remains considerable uncertainty about the effectiveness of mitigation measures that are in place (see, for example, Weir *et al.,* 2006) and few areas offer wide scale protection through seasonal closures (Dolman, 2006). In addition, because of new technological developments, it is apparent that the industry is increasingly moving further offshore into deeper waters.

Looking at this in more detail, although some regions such as Canada and Europe are showing a decline in both the number of areas having been surveyed and the number of crews operating, five of the eight regions are showing an increase in the number of areas surveyed. These are the USA, Africa, the Commonwealth of Independent States, the Middle East and the Far East. The available data also suggest that seismic surveys have been carried out over a greater number of areas in the Far East and the USA than in the rest of the world. Latin America has shown a constant number of areas in which surveys have been carried out.

The number of crews operating has decreased worldwide (see Figure 1), with the Far East being the only area in which the number of crews operating constantly increased over the ten year period (see Figure 9). Some regions in which surveys have declined or remained level, like the USA, are expected to see increased surveying over the next several years. Generally, the number of areas undergoing seismic surveys worldwide appears to be increasing (see Figure 2).

However, the data are difficult to interpret, due to their varying quality and are, therefore, of limited use in terms of making solid conclusions. In particular, the number of areas in which seismic surveys are being carried out cannot be accurately determined until data are reported in a uniform manner.

We therefore conclude that as uniformity in reporting is vital to our understanding of the extent of seismic surveys both globally and regionally and the potential impacts on marine fauna, reporting should be standardised, mandatory and transparent throughout the global industry.

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Appendix

Figure 1

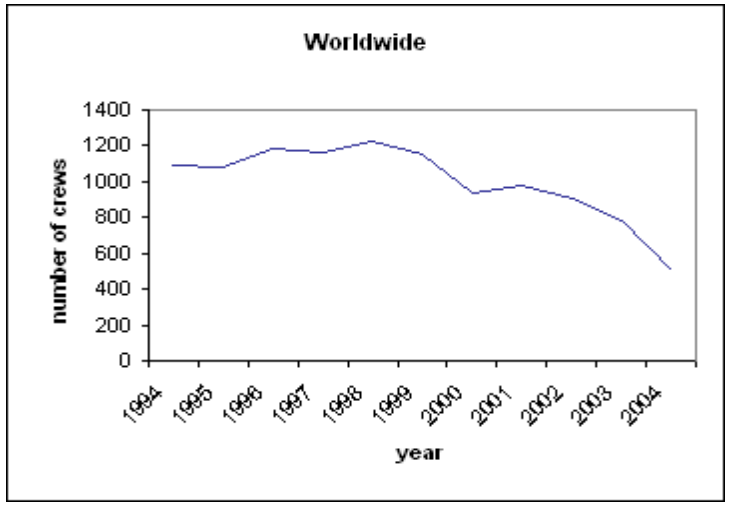


Figure 2

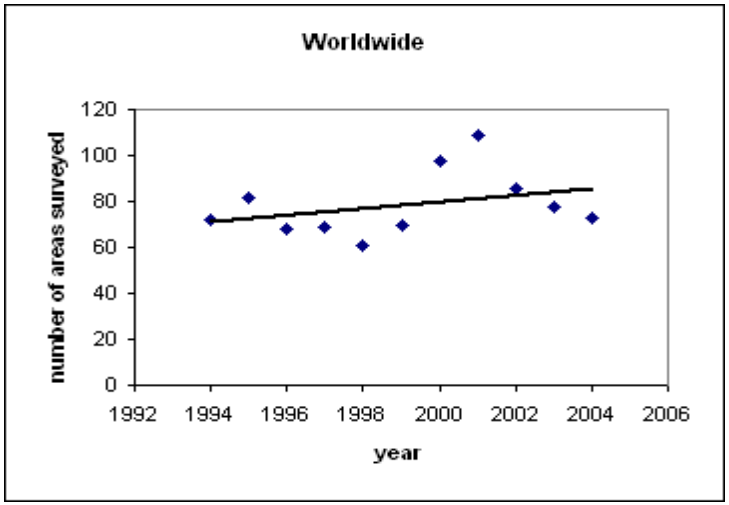


Figure 3

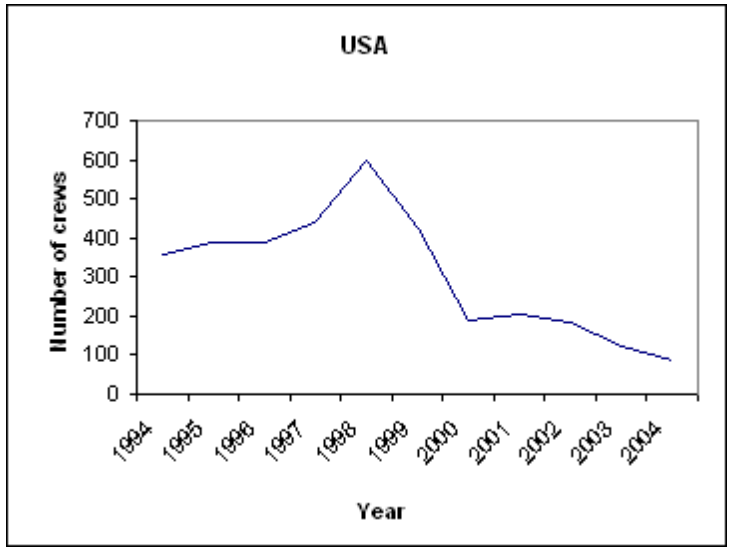


Figure 4

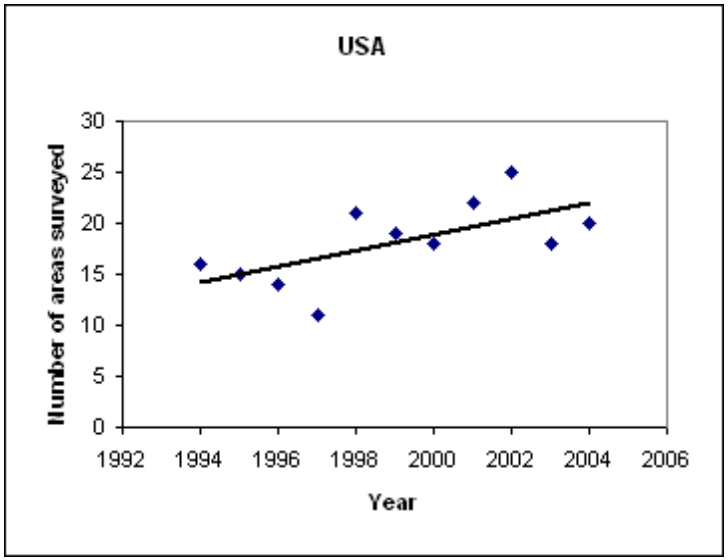
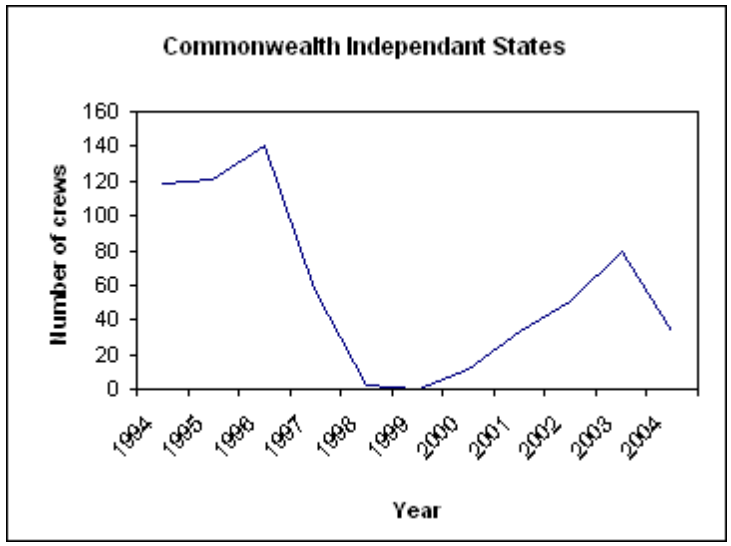


Figure 5



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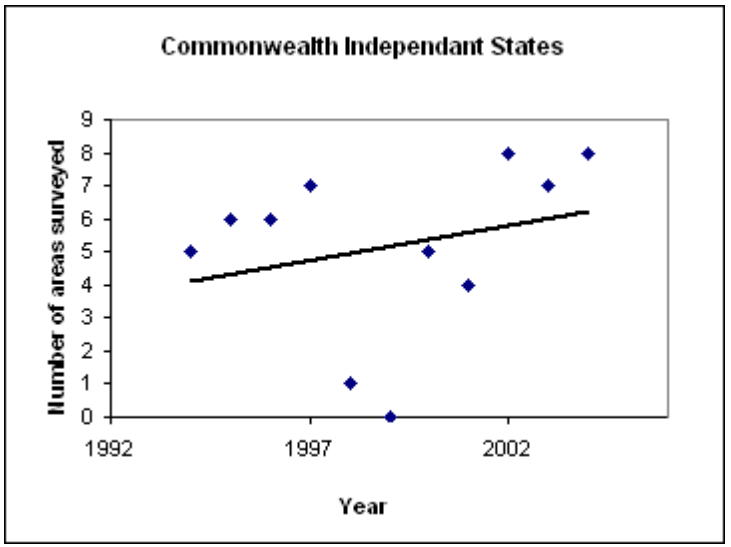

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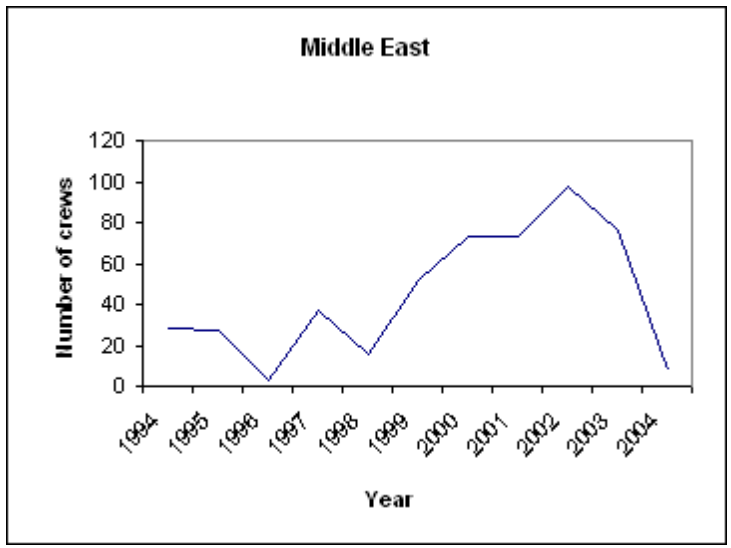

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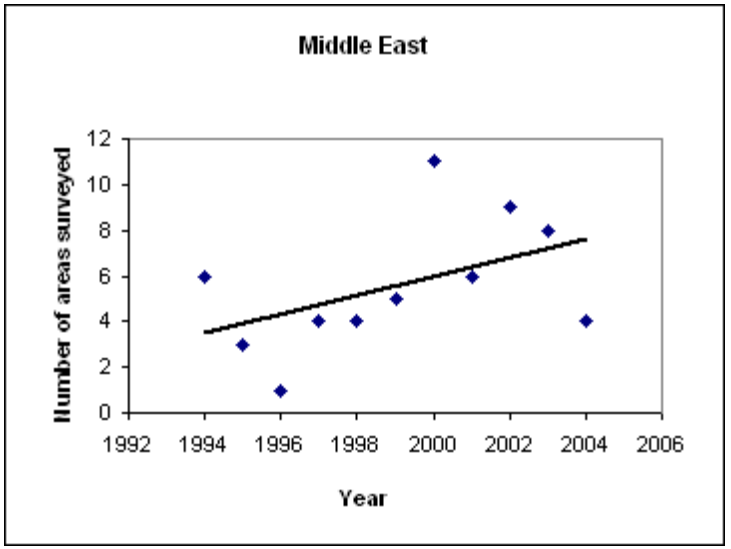
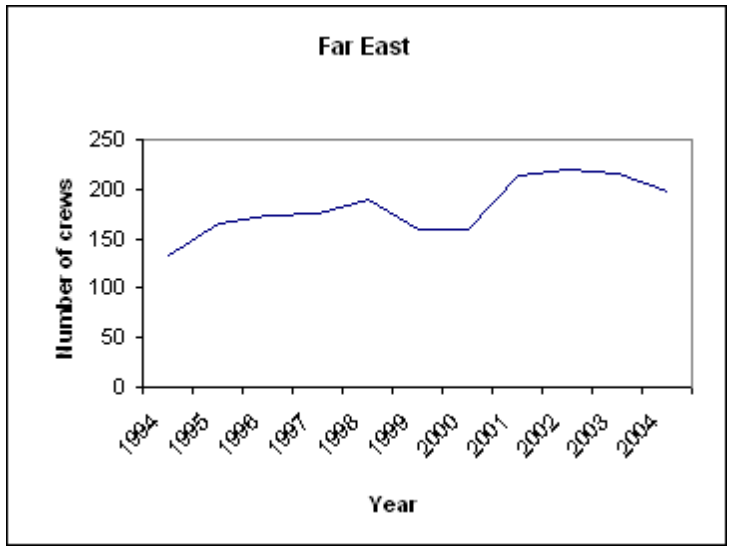


Figure 9



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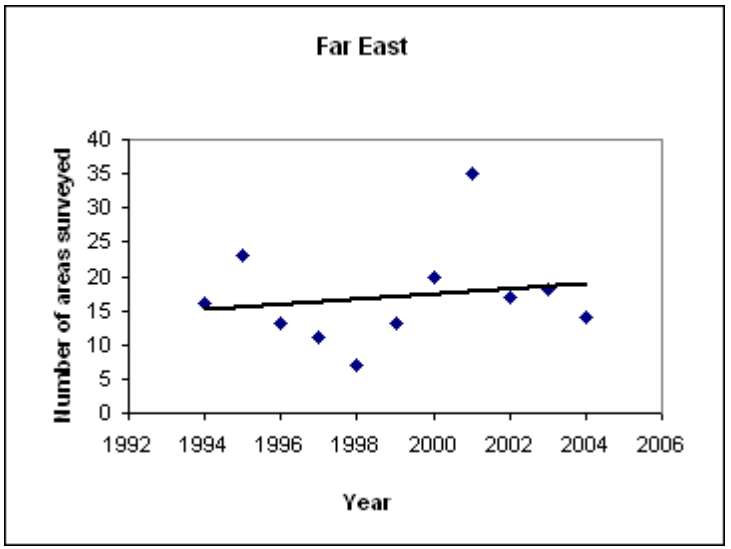
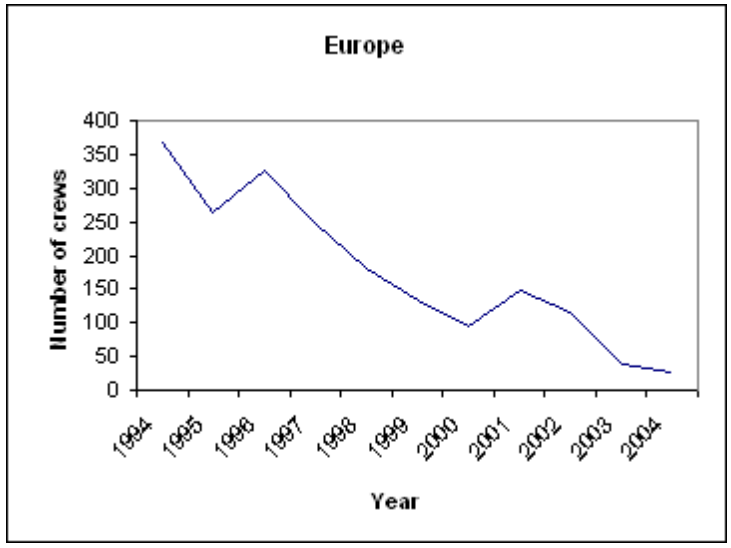


Figure 11



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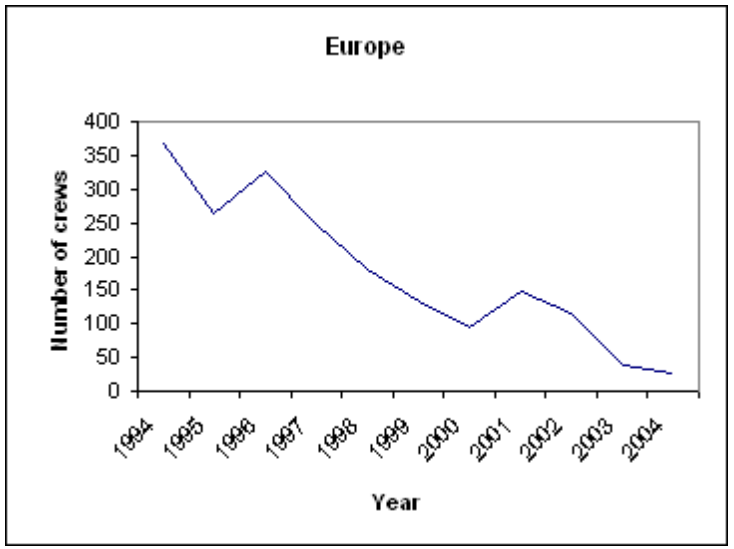

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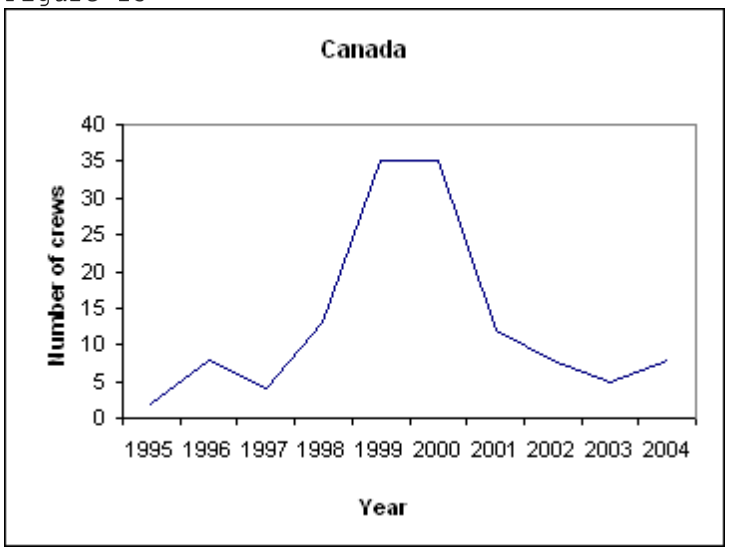

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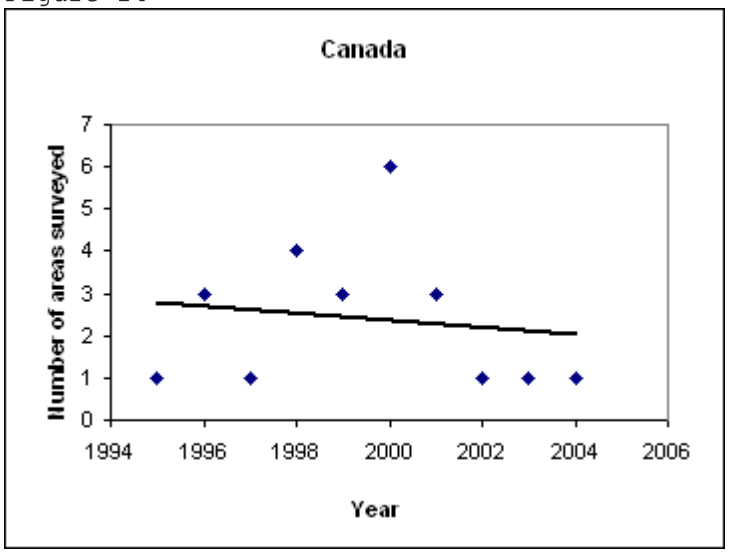

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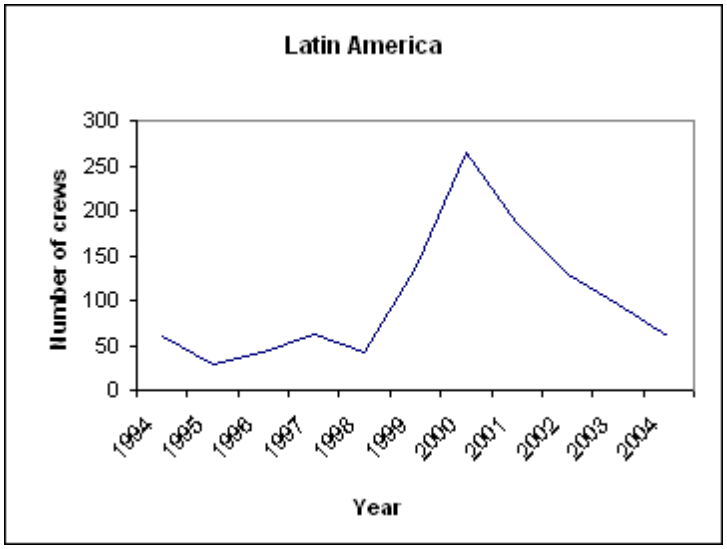

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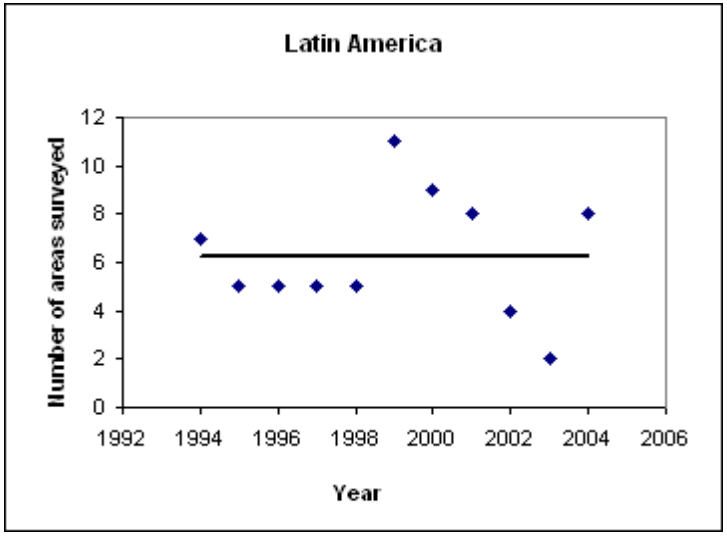

Figure 17

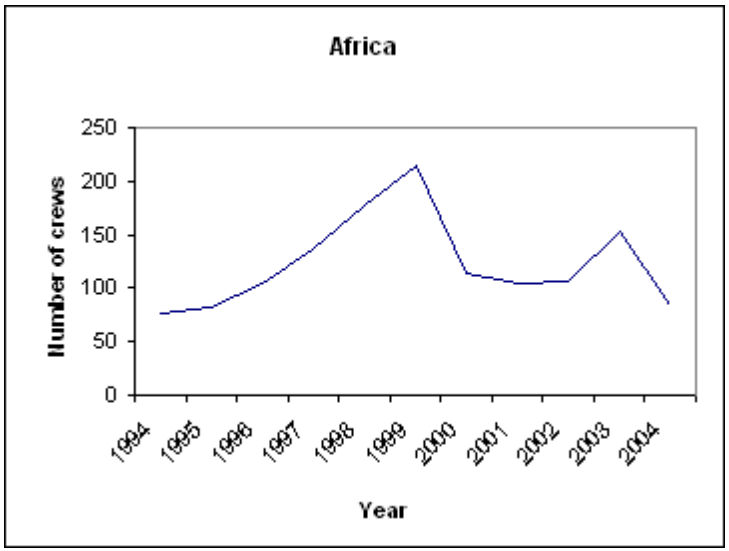

Figure 18

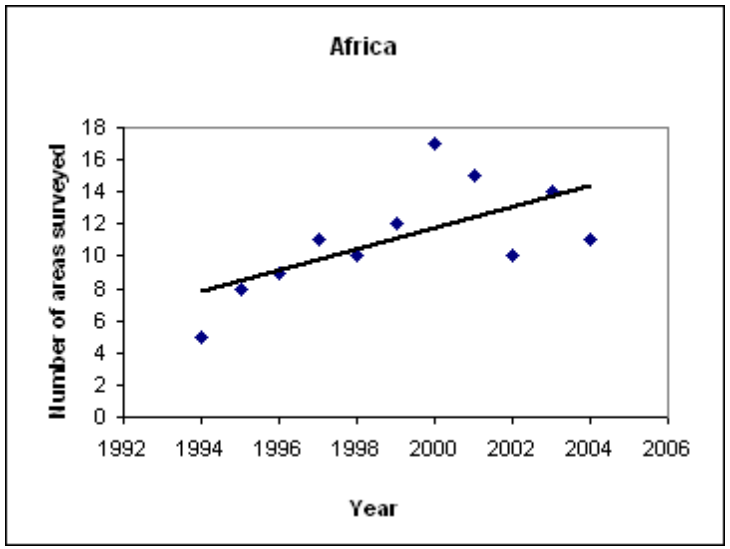

Table 1

Area	% of monthly reports from undisclosed locations
USA	20.8
Middle East	19.6
CIS	10
Latin America	8.9
Far East	8.1
Africa	6.5
Europe	2.9
Canada	0
Global	9.6