Trends in chronic marine oil pollution in Danish waters assessed using 22 years of beached bird surveys

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Abstract

Beached bird surveys provide an important tool for monitoring the level of oil pollution at sea, which is the most significant observable cause of death for a large number of waterbird species and pose a serious threat to wintering seabird populations. Linear regression analyses of oil rates from the Danish twenty-two year dataset show a decline in the oil pollution level in offshore areas of the eastern North Sea and Skagerrak, in the Wadden Sea and in near-shore parts of the Kattegat; but a worsening in the offshore areas of the Kattegat. These results raise concern for species such as common scoter, velvet scoter, eider and razorbill, for which the Kattegat serves as a globally important wintering area. It is recommended that surveillance for oil spills is intensified in inner Danish waters, and that action is taken to make responses towards offenders faster, and penalties for oil seepage higher.

Keywords: Beached bird surveys; chronic marine oil pollution; monitoring; seabirds; oil rate; linear regression

1. Introduction

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Oil-contaminated seabirds have attracted attention since the beginning of the 20th century as oil production and shipping has increased. Oil is the most easily observed mortality factor on stranded birds, although it is hard to say to what degree populations are affected. Beached bird surveys (BBS) are best used to monitor long-term changes in the level of chronic oil pollution (Furness and Camphuysen, 1997; Camphuysen and Heubeck, 2001). Seabirds can be viewed as objects in regular contact with the sea surface and the oil rate calculated as the proportion of oiled birds out of the total number of birds found has proven as a highly robust measure reflecting the level of oil pollution in the bordering sea areas (Camphuysen, 1998; Fleet and Reineking, 2000b; Camphuysen and Heubeck, 2001). It can therefore function as an efficient tool in detecting trends in the level of marine oil pollution. The ability to assess the level of oil pollution by the amount of oil on the water rather than the number of oil spills in particular makes BBS an important monitoring instrument, and a powerful one when used in conjunction with naval surveillance flights.

Danish waters include areas of international importance to several species of marine birds during wintering and moulting periods. The most important areas are the Kattegat, the Skagerrak and the German Bight; the northern Kattegat is considered to be the most globally important wintering area for the common scoter *Melanitta nigra* and razorbill *Alca torda* (Durinck et al., 1994; Skov et al., 1995).

It is illegal to discharge any amount of oily substances into Danish waters, and both the Baltic Sea (including the belts and the Kattegat) and the North Sea (from 1999) are designated as Special Areas under the International Convention for the Prevention of Pollution from Ships convention, (MARPOL 73/78, Annex 1), International Maritime Organization (IMO). The Wadden Sea was designated as a Particularly Sensitive Sea Area (PSSA) in 2002, and from 2007 the protection of the Baltic Sea will be increased further when the area is designated as a PSSA. Until the late 1990's the surveillance of Danish waters and enforcement of laws against marine pollution was undertaken by the Danish Environmental Protection Agency. In 2000 this role was taken over by the Danish Navy, who have since increased surveillance intensity.

A national BBS programme was set up in Denmark in 1985 by the Danish Ornithological Society (DOF-BirdLife Denmark) following a pilot study carried out on the Danish North Sea coast in 1984 (Danielsen et al., 1986). The national survey programme has contributed to the International Beached Bird Survey scheme

(IBBS) (Skov et al., 1989) as well as to the monitoring activities related to the management of the Wadden Sea (Camphuysen et al., 2005). Results of the Danish monitoring programme have been published with regular intervals in reports to the Danish Environmental Protection Agency (Skov et al., 1996; Durinck and Skov, 2001).

2. Materials and methods

2.1. Study area and study design

Data on beached birds from Danish beaches in all regions of the country were recorded yearly during two coordinated censuses at the end of the months of February and March. A large number of volunteer observers participated in the census. In 1985 (winter 1984/1985) counts were conducted in November, January and March. From 2004 onwards only one yearly census at end of February was carried out. Surveys from larger oil spills are not included in this dataset. The cumulative effort (km patrolled) for each sub-region per survey year is shown in Table 1.

As Danish sea areas vary highly in physical and hydrographical conditions five sub-regions are defined (Fig. 1) in concordance with the sub-regions defined in previous reports (Skov et al., 1996; Durinck and Skov, 2001):

Sub-region 1, the Danish part of the Wadden Sea
Sub-region 2, west coast of Jutland bordering the North Sea and Skagerrak
Sub-region 3, the Kattegat
Sub-region 4, the Belts and western Baltic Sea
Sub-region 5, the island of Bornholm in the Baltic Sea

The west coast of Jutland is generally characterized by wide, flat sandy beaches influenced by the northward running Jutland Current (Nørrevang and Lundø, 1979), whereas the beaches in the eastern part of Denmark in contrast are more sheltered with a higher density of terrestrial scavengers (mainly Red Fox *Vulpes vulpes*). These conditions result in a considerably lower encounter rate of stranded bird corpses in eastern Denmark.

2.2. Data collection

Collection of data followed the guidelines set up by The Joint Assessment and Monitoring Programme under the OSPAR Commission (OSPAR, 1995). The information recorded for each patrol includes date, site, observer, km patrolled, km with visible oil contamination, and for every encounter of a stranded bird the following information was recorded: species; presence of oil in feathers; whether the individual was a whole corpse or only body parts.

2.3. Indicator species/groups

As natural mortality rates as well as the vulnerability to oil pollution vary for different species it is important to analyse data for different species separately. However, in order to acquire sufficient sample sizes, data for related species showing the same vulnerability to oil pollution can be pooled. Mortality rates also have a high level of temporal variation, and analyses should therefore be carried out only on data collected at the same time of year (Camphuysen and Heubeck, 2001; Seys et al., 2002). A further point that emphasizes the importance of analyzing data separately for species groups is that the oil rate is dependant on the time spent on the water surface. Pelagic species as auks and scoters tend to have higher oil rates than more aerial species as e.g. fulmar *Fulmarus glacialis* and gulls. Though the level of oil rates may vary between regions, the ranking of species with respect to oil rate often does not (Camphuysen and Heubeck, 2001).

Groups of species with similar oil pollution vulnerability for which sufficient sample sizes could be obtained were used as indicator species/groups:

Fulmar: Sub-region 2

Eider *Somateria mollissima*: Sub-regions 1, 3 & 4

Scoters (*Melanitta* spp.): Sub-regions 1, 2 & 3

Gulls (*Larus* spp.): Sub-regions 1, 2, 4 & 5

Kittiwake *Rissa tridactyla*: Sub-regions 1 & 2

Auks (Guillemot *Uria aalge*, razorbill, black guillemot *Cepphus grylle*, little auk *Alle alle*, puffin *Fratercula arctica*): Sub-regions 1, 2 & 3

Coastal (grebes *Podiceps* spp., cormorant *Phalacrocorax carbo*, swans *Cygnus* spp., geese and ducks Anatidae, common gull *Larus canus*): Sub-region 2

Wildfowl (swans, geese and ducks, coot *Fulica atra*): Sub-regions 3 & 4

Datasets for common scoter in sub-region 1 and for guillemot and razorbill in sub-region 2 were large enough to allow separate testing and were therefore not pooled into the larger species groups.

2.4. Data analyses

Oil rates were calculated as the proportion of dead birds with oil in the plumage out of the total number of dead birds found. Only data on whole corpses were used.

In order to be able to apply linear trend analyses, oil rates were transformed using the arcsine transformation formula recommended by Krebs (1999) and rescaled to range between 0 and 1 by multiplying with 2/π (McCune and Grace, 2002). The full equation is therefore:

$$\textit{Transformed oil rate} = \frac{2}{\pi} \times \arcsin\left(\sqrt{\textit{oil rate}}\right)$$

Transformed oil rates were analysed by least squares linear regression and only years with sample sizes of ≥10 individuals were included in the regression analyses. All data transformations and regressions were performed using GraphPad Prism version 4.03 for Windows (GraphPad Software, 2005). Correction for spurious significant P-values when performing multiple similar tests was carried out by incorporating the sequential Bonferroni procedure for each sub-region (Rice, 1989). Results are ranked by their P-values (P_i) and will remain significant only if the following expression is justified:

$$P_i \le \frac{\alpha}{1 + k - i}$$

where α = significance level (0.05 and 0.01), k = number of tests and i = the test result's rank.

Estimated oil rates for significant regression slopes were found by calculating the intercept of the regression line in 2005 and back-transforming the values. Mean oil rates for indicator species/groups were calculated for the whole 22-year period as the number of oiled individuals divided by the species total in order to compare oiling rates across subregions.

A retrospective power analysis (Thomas, 1997; Thomas and Krebs, 1997) was performed to evaluate the amount of type II error in the dataset. Power as a function of the coefficient of determination (r^2) in a 22-year dataset was computed together with a calculation of the minimum sample size required yielding a power of 0.8. All power and sample size calculations were carried out in the program Power and Precision version 2.1 (Borenstein, 2001) and α was set to 0.05 in both analyses.

3. Results

The linear regression analyses showed significant negative trends for fulmar, guillemot and razorbill for sub-region 2. Scoters showed a significant positive trend for sub-region 3, while the trend for wildfowl was significantly negative for this sub-region. Although not significant, auks showed a positive trend for sub-region 3. No species or groups showed significant trends in sub-regions 1, 4 and 5, although for sub-region 1, eider and gulls showed a tendency towards a negative slope (eider: slope = -0.045 ± 0.006, F = 2.786, P = 0.119; gulls: slope = -0.006 ± 0.004, F = 2.451, P = 0.134). Results of the regression analyses are summarized in Table 2 and significant regression analyses are shown in Fig. 2 (sub-region 2) and Fig. 3 (sub-region 3).

Tests for differences in slope between significant regression slopes within sub-regions showed that slopes were not significantly different for species in sub-region 2 (fulmar, guillemot and razorbill) with P = 0.187 (F = 1.738, DFn = 2, DFd = 49). It is therefore possible to calculate one slope for these species giving a pooled slope for sub-region 2 of -0.015. Significant slopes from sub-region 3 were significantly different as they were negative for wildfowl while positive for common scoter (P < 0.001, F = 21.617, DFn = 1, DFd = 11) making pooling of slopes impossible. Estimated oil rates in 2005 for significant regression slopes are listed in Table 3 and mean oil rates for indicator species/groups calculated over the whole period are shown in Table 4. Table 5 lists the results of the power analysis for 22 years of sampling together with calculations of the minimum number of years of sampling yielding a power of 0.8 in relation to the level of sampling variance measured by r^2.

4. Discussion and conclusions

4.1. Factors affecting oil rate and power of method

At least two factors, apart from chronic oil pollution, affect the oil rate of beached birds. The first is increased natural mortality caused by events such as extreme weather conditions or epidemics causing crashes in populations. The second is major oiling incidents (Fleet and Reineking, 2000a; Fleet and Reineking, 2000b). Natural mortality acts mainly on a regional scale and lowers the oil rate for the affected species, while major oiling incidents act primarily on a local scale increasing the oil rate. Epidemics will often affect only one, while extreme weather conditions and major oiling incidents usually affect the oil rate for all, or a broad range of species.

If it is suspected that the oil rate for certain species has been skewed in either direction by increased natural mortality or local incidents in a particular year, it can be argued that these data should be omitted from the analysis. However, these instances will most likely result in a type II error rather than a type I error as they, due to the stochasticity, increase the variation in the dataset. In order to quantify the level of type II error a power analysis was performed. With a sample size of 22 years it is seen (Table 5) that power exceeds 0.8, which is often considered adequate (Cohen, 1988) at a coefficient of determination (r^2) value of around 0.3. Although r^2 values of this magnitude are found in the dataset (Table 2) it is also evident that r^2 for many indicator groups is much lower. As the coefficient of determination (r^2) incorporates both the trend and the sampling variance (Thomas, 1997) weak trends will need very large samples for the power to reach 0.8. I.e. values of r^2 below 0.3 require considerably larger sample sizes than 22 years as in the present study in order to attain the power level of 0.8. Furthermore, sample sizes for less abundant species are often smaller than the number of years with sampling as sufficient sample sizes for data analysis are not obtained every year. Therefore power will often only reach a desired level for the most abundant species/indicator groups. The way to increase power in BBS is to ensure that sample sizes each year are as large as possible by maximizing the number of patrolled beaches. Increasing the number of annual censuses should also be considered an option.

4.2. Trends in oil pollution level for sub-regions

The results of the Danish BBS programme suggest a general decline in the marine oil pollution level. However, some marked deviances from this pattern are seen for some species in some of the sub-regions. The Wadden Sea (sub-region 1) has generally seen a tendency towards a reduction in the amount of oil pollution although none of the linear regression analyses were significant. Tendencies were seen in eider and gulls. This suggests a slight improvement during the survey period. Sub-region 1 is under influence of the northward running Jutland Current (Nørrevang and Lundø, 1979) bringing water to the area from the southern part of the Wadden Sea and inner parts of the German Bight. The results from this sub-region can therefore be seen as a reflection of the oil pollution situation of the German Bight where there has been a significant improvement in the pollution level from the 1980's and continuing into the 1990's (Camphuysen, 1998; Fleet and Reineking, 2001; Camphuysen et al., 2005).

Several species or groups of species showed a decline in oil rate in sub-region 2. Auks and fulmar showed significantly declining oil rates suggesting an improvement in the oil pollution level in offshore areas of the North Sea and the Skagerrak. This drop in the oil pollution level can possibly, in part, be a result of the North Sea being designated as a Special Area in 1999 under the MARPOL Annex 1 (IMO) making the North Sea a zero-discharge zone (Fleet and Reineking, 2000b) as well as the Danish Navy taking over the surveillance of the marine environment and enforcement of laws against oil pollution from 2000 onwards, although there are no clearly visible changes in oil rates after 1999/2000. The Danish Navy has both increased the number of flying hours and carried out surveillance with more effective planes as well as with satellites, which could explain a more gradual change. It was not possible to detect any changes in oil rates for coastal species in sub-region 2 (Table 2) suggesting that the positive offshore development in the pollution level seen in the region is not apparent for the species inhabiting the coastal current.

In contrast to the situation in sub-region 2, the results for sub-region 3 showed a significant increase in oil rates for offshore species (scoters), whereas coastal species (wildfowl) showed a significant decline. This result suggests an increase in the pollution level in sea areas with heavier traffic, perhaps related to increased traffic through the area. The Admiral Danish Fleet has monitored the traffic through the Great Belt from the Vessel Traffic Service (VTS) at Korsør since 1994 and has recorded an increase in the traffic through the belt over the last three years (Admiral Danish Fleet, 2005b). However, the traffic level is not currently higher than it was ten years ago. The reasons for the sharp decline in oil rates of wildfowl species remain unclear, and unfortunately the data was insufficient in the second half of the survey period. It is therefore impossible to judge whether or not the low level has remained in recent years. It should be noted that there are few data for common scoter in the second half of the survey period, and local oiling incidents might therefore have a greater influence on the oil rate. It appears that the oil pollution level has risen in sub-region 3 but this might not be entirely caused by chronic oil pollution.

In sub-region 4 the results show a more or less unchanged situation for the analysed species. The oil pollution level in coastal areas appears to have remained fairly low. It is not possible to conclude on the pollution level in offshore areas of sub-region 4 as data for offshore species are lacking.

For sub-region 5 only a small fraction of the study period has yielded data. It is therefore not possible to assess the trend in the oil pollution situation or the current level of marine oil pollution in the Danish part of the Baltic Sea.

Overall, the analyses showed a high number of non-significant trends. This may indicate no-change situations in the particular areas, but might also in some cases be caused by a shortage of data or high annual variance causing low power.

The general tendency of an improvement of the oil pollution level with the exception of the Kattegat is consistent with surveillance data from the Danish Navy that show a minor decline in the number of confirmed oil spills since the late 1990's (Admiral Danish Fleet, 2005a).

4.3. Differences in pollution level between sub-regions

The results of the Danish survey show a reduction in the pollution level in offshore areas of the North Sea. However oil rates are still much higher than oil rates for the same species in the Wadden Sea. This may reflect the greater effort to protect the Wadden Sea area as this was designated as a Particularly Sensitive Sea Area (PSSA) from 2004 (Reineking, 2002) and it is consistent with the results of the oil pollution monitoring conducted in the southern North Sea (Camphuysen et al., 2005). Future years will show if the level in the North Sea continues to drop, or if the decline will level off. If surveillance and law enforcement is increased in this area there is a good chance that levels of oil pollution will fall to levels resembling those of the Wadden Sea. The positive situation in the Wadden Sea is reflected in the low oil rate for gulls, although the problem with oil pollution has not been overcome in the region as common scoter still suffers oil rates of around 0.75.

The situation in the inner waters of Denmark (sub-regions 3 and 4) is less promising as the increase in pollution level in offshore areas has now lead to oil rates of close to 1 for at least common scoter and a number of auk species in the Kattegat. Auks show a gradual increase in oil rate going from the Wadden Sea over the North Sea to the Kattegat where oil rates are close to 1.

It has not been possible to follow the oil pollution tendencies in the Baltic Sea around the island of Bornholm (sub-region 5) due to the lack of data. Judging from the few gull data available it seems that the level, at least in the beginning of the survey period, has been relatively low. It is hoped that the project in near future will succeed in attracting observers so that the oil pollution will also be monitored in these waters.

4.4. Conclusions

Although the results in general show a reduction in the marine oil pollution level it is evident that the species that are most affected by oil pollution are the species that spend more time on the sea surface. These include common scoter and razorbill for which Danish waters play a significant part during winter (Durinck et al., 1994; Skov et al., 1995). This issue should therefore be under special concern as the increase in oil pollution level over the last two decades in the Kattegat may have long-term consequences and could be critical for these species. Although it is uncertain to what extent seabird populations using Danish waters for wintering are affected, it is suggested that the level of chronic oil pollution at present poses a serious threat and action is required to lessen the mortality within these important populations. It is recommended that protection of the Kattegat is intensified in terms of increased surveillance for oil spills, faster response towards offenders and higher penalties.

Acknowledgements

We wish to thank the large number of volunteer observers participating in the Danish Ornithological Society's annual bird counts in the beached bird survey. Special thanks go to the local coordinators for their work and commitment through all the years. Thank you to Kasper Thorup, Anders P. Tøttrup and Thomas Niebuhr for assistance with data analyses and to Suzanne Rachel Livingstone for helpful comments on the manuscript.

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Fig. 1. Danish sea areas and sub-regions used in the Danish beached bird survey.

Fig. 2. Significant regression analyses for sub-region 2 with 95 % confidence limits.

Fig. 3. Significant regression analyses for sub-region 3 with 95 % confidence limits.

Figure 1

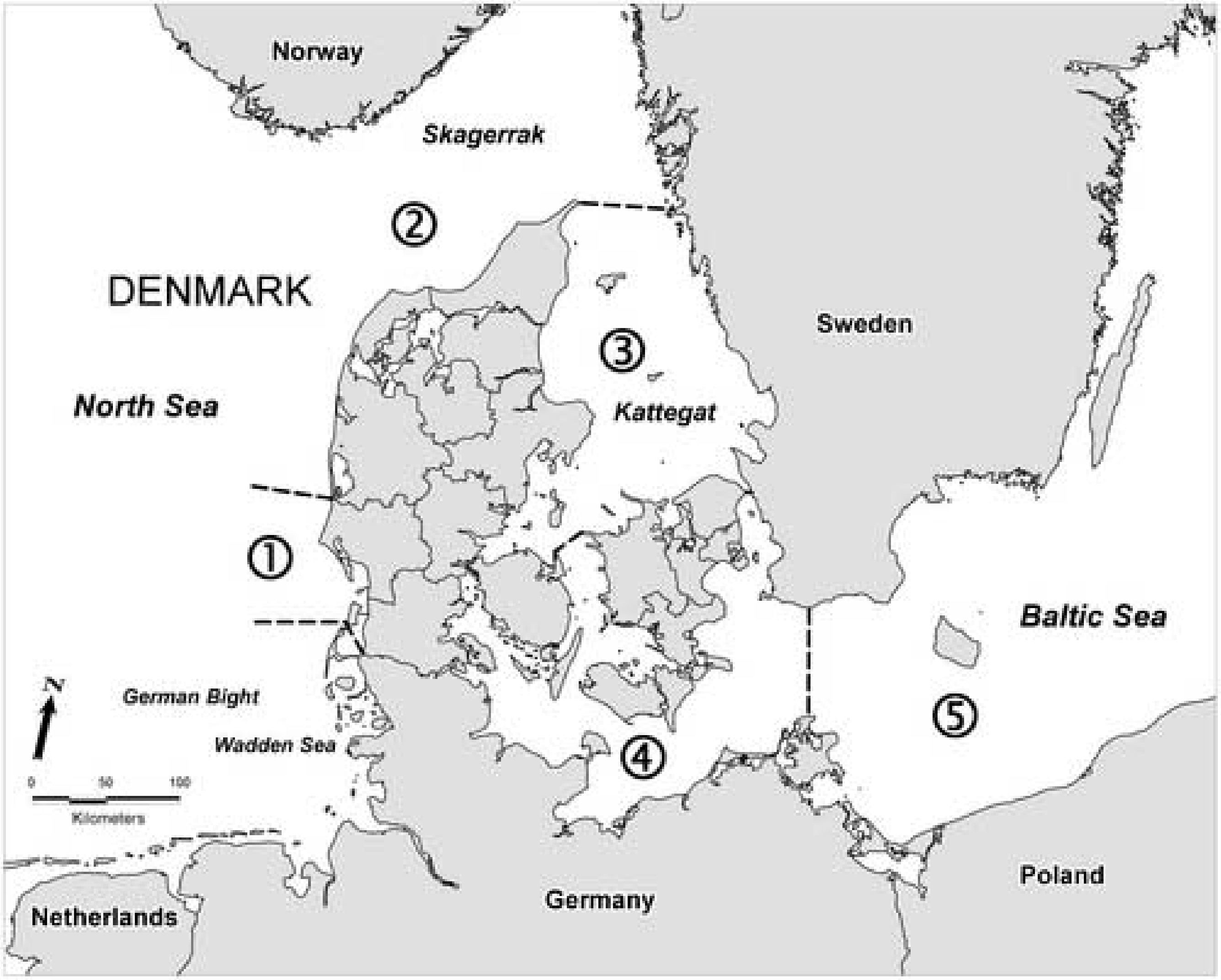

Norway
Skagerrak
②
DENMARK
③
Sweden
North Sea
Kattegat
①
Baltic Sea
N
German Bight
⑤
Wadden Sea
④
0
50
100
Kilometers
Poland
Germany
Netherlands

Figure 2

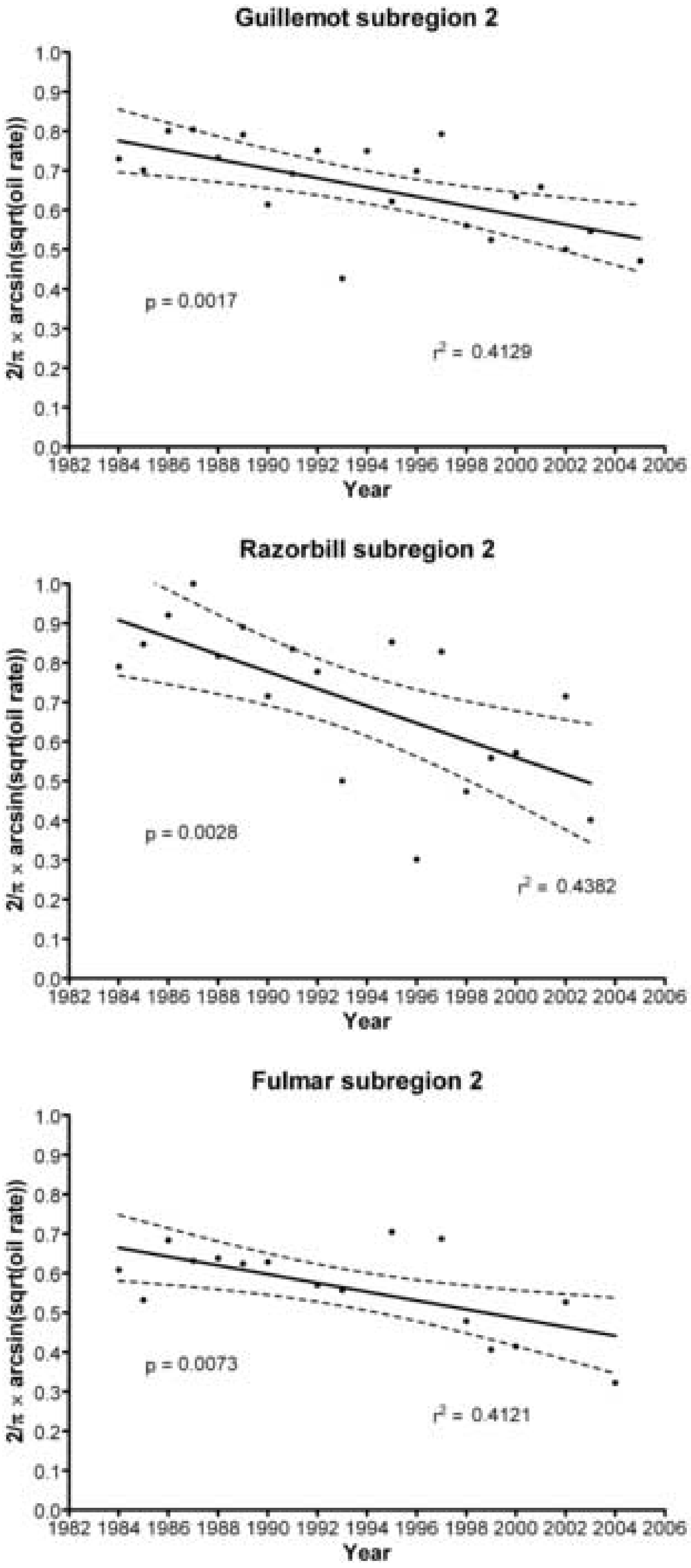
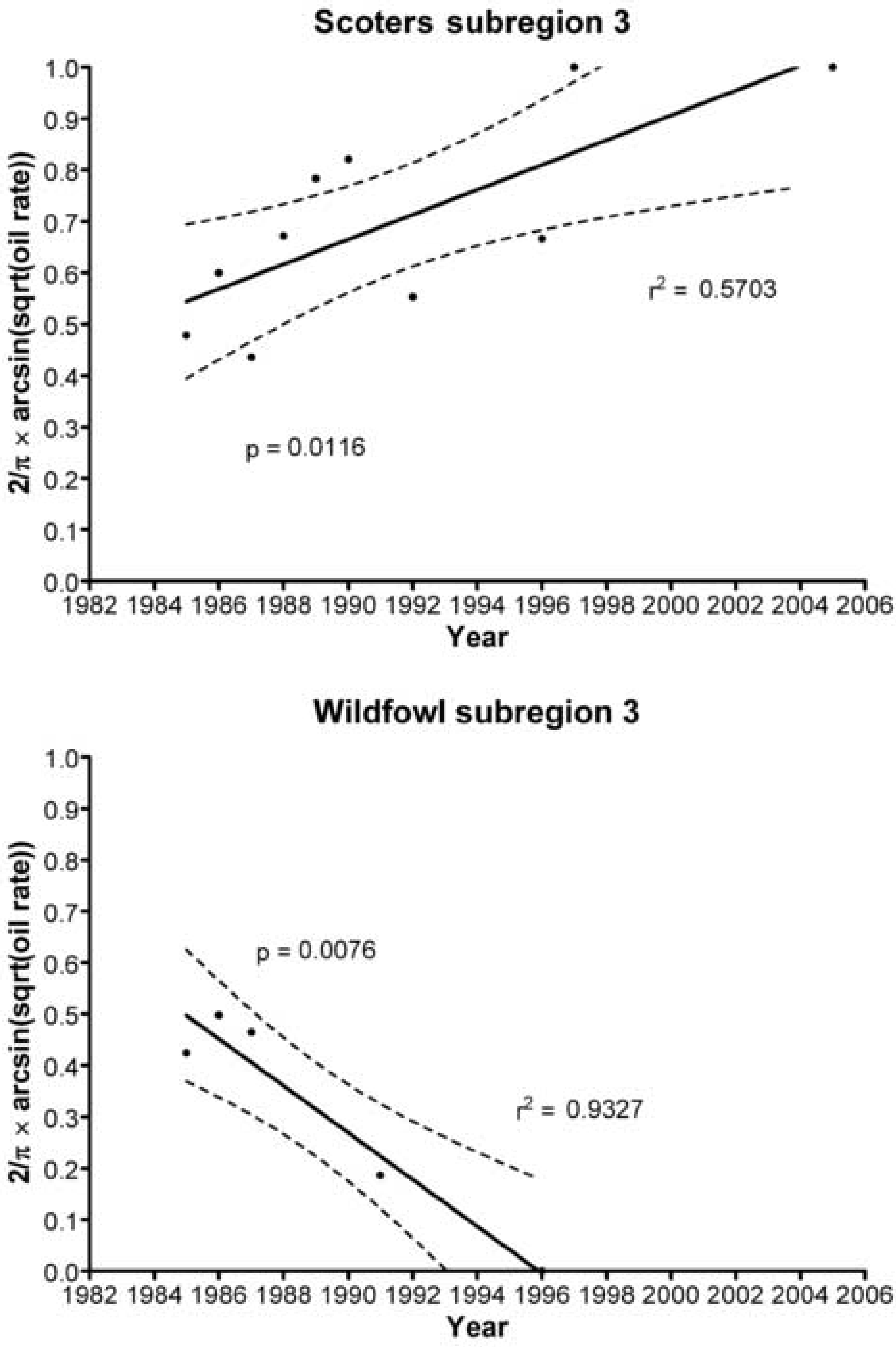

Guillemot subregion 2
2/π × arcsin(sqrt(oil rate))
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006
Year
p = 0.0017
r² = 0.4129
Razorbill subregion 2
2/π × arcsin(sqrt(oil rate))
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006
Year
p = 0.0028
r² = 0.4382
Fulmar subregion 2
2/π × arcsin(sqrt(oil rate))
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006
Year
p = 0.0073
r² = 0.4121

Figure 3



Scoters subregion 3
2/π × arcsin(sqrt(oil rate))
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
r^2 = 0.5703
p = 0.0116
1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006
Year
Wildfowl subregion 3
2/π × arcsin(sqrt(oil rate))
1.0
0.9
0.8
0.7
0.6
0.5
0.4
0.3
0.2
0.1
0.0
p = 0.0076
r^2 = 0.9327
1982 1984 1986 1988 1990 1992 1994 1996 1998 2000 2002 2004 2006
Year

Table 1

Table 1

Total effort (km patrolled) per year and effort per year divided into sub-regions (see Fig. 1).

	Kilometres patrolled per sub-region					
Year	**1**	**2**	**3**	**4**	**5**	**Total**
1984	100	330	0	0	0	430
1985	220	525	500	220	0	1,465
1986	260	450	625	160	0	1,495
1987	280	310	420	290	95	1,395
1988	130	240	620	415	105	1,510
1989	90	275	410	355	85	1,215
1990	65	405	295	315	90	1,170
1991	60	310	340	275	90	1,075
1992	105	480	230	205	60	1,080
1993	40	300	115	130	65	650
1994	35	80	25	45	0	185
1995	55	180	20	75	0	330
1996	13	138	107	80	0	337
1997	84	138	129	60	0	411
1998	58	213	124	79	0	473
1999	58	165	126	81	0	430
2000	106	291	98	66	0	561
2001	79	275	98	51	0	503
2002	133	224	118	27	0	501
2003	93	215	111	26	0	444
2004	83	181	136	56	0	454
2005	39	204	127	25	0	394

Table 2

Table 2

Results of linear regression analyses on arcsine transformed oil rates for indicator species/species groups. Significance indications after correction with the sequential Bonferroni procedure (see text) are ** = P < 0.01, * = P < 0.05 and NS = Not significant. Parentheses indicate significance before Bonferroni correction.

Sub-region	Species/group	N	Slope		r^2	F	DFn, DFd	P	Deviation from zero
1	Eider	15	-0.04500	± 0.005768	0.1765	2.786	1, 13	0.1190	NS
	Common scoter	17	0.00470	± 0.009237	0.0169	0.258	1, 15	0.6186	NS
	Gulls	21	-0.00622	± 0.003973	0.1143	2.451	1, 19	0.1339	NS
	Kittiwake	10	-0.00607	± 0.009584	0.0478	0.401	1, 8	0.5441	NS
	Auks	17	-0.00833	± 0.006741	0.0924	1.527	1, 15	0.2356	NS
2	Fulmar	16	-0.01113	± 0.003553	0.4121	9.814	1, 14	0.0073	* (**)
	Scoters	7	0.01463	± 0.01162	0.2407	1.585	1, 5	0.2636	NS
	Coastal	11	0.01672	± 0.01116	0.1996	2.244	1, 9	0.1684	NS
	Gulls	17	0.00341	± 0.006450	0.0183	0.279	1, 15	0.6050	NS
	Kittiwake	11	-0.01226	± 0.008915	0.1737	1.892	1, 9	0.2022	NS
	Guillemot	21	-0.01179	± 0.003227	0.4129	13.360	1, 19	0.0017	* (**)
	Razorbill	18	-0.02180	± 0.006169	0.4382	12.480	1, 16	0.0028	* (**)
3	Eider	18	0.00315	± 0.01032	0.0058	0.093	1, 16	0.7640	NS
	Scoters	10	0.02413	± 0.007406	0.5703	10.620	1, 8	0.0116	*
	Wildfowl	5	-0.04566	± 0.007083	0.9327	41.570	1, 3	0.0076	* (**)
	Auks	9	0.01192	± 0.01117	0.1400	1.139	1, 7	0.3212	NS
4	Eider	10	-0.01122	± 0.02450	0.0255	0.210	1, 8	0.6593	NS
	Wildfowl	10	0.00028	± 0.01171	0.0001	0.001	1, 8	0.9818	NS
	Gulls	11	-0.01360	± 0.01579	0.0761	0.741	1, 9	0.4116	NS
5	Gulls	6	-0.04440	± 0.02422	0.4565	3.360	1, 4	0.1408	NS

Table 3

Estimated oil rates in 2005 for significant regressions calculated by back-transforming the 2005-intercept values.

Sub-region	Species/group	2005 intercept	Estimated oil rate
2	Fulmar	0.4344	0.40
	Guillemot	0.5410	0.56
	Razorbill	0.4410	0.41
3	Scoters	1.0207	1.00
	Wildfowl	-0.4083	0.00

Table 4

Table 4

Mean oil rates for the whole 22-year period for indicator species/groups calculated as the total number of oiled individuals (Oiled) divided by the species total (N).

Sub-region	Species	n (years)	N (birds found)	Oiled	Mean oil rate
1	Fulmar	8	98	21	0.214
	Eider	22	916	398	0.434
	Scoters	21	1,630	1,241	0.761
	Gulls	22	878	79	0.090
	Kittiwake	19	367	180	0.490
	Auks	21	1,245	659	0.529
2	Fulmar	21	632	322	0.509
	Gulls	22	1,031	459	0.445
	Kittiwake	21	603	296	0.491
	Auks	22	4,550	3,263	0.717
3	Eider	21	848	438	0.517
	Scoters	19	247	177	0.717
	Wildfowl	15	395	142	0.359
	Gulls	10	74	17	0.230
	Auks	19	287	247	0.861
4	Eider	21	799	245	0.307
	Wildfowl	17	910	142	0.156
	Gulls	21	638	84	0.132
5	Gulls	7	256	45	0.176

Table 5

Power analysis (sample size of 22 years) and minimum sample sizes required (yielding a power of 0.8) for an increasing coefficient of determination (r^2). α-level for both analyses was set to 0.05.

r^2	Power for sample size of 22 years	Minimum sample size (years) for power of 0.8
0.05	0.18	152
0.10	0.32	73
0.15	0.47	47
0.20	0.61	34
0.25	0.73	26
0.30	0.83	21
0.35	0.91	17
0.40	0.95	14
0.45	0.98	12
0.50	0.99	11
0.55	1.00	9
0.60	1.00	8
0.65	1.00	7
0.70	1.00	6
0.75	1.00	6
0.80	1.00	5
0.85	1.00	5
0.90	1.00	4
0.95	1.00	4