Belg. J. Zool., 132 (2): 111-118 July 2002

Long-term changes in oil pollution off the Belgian coast: evidence from beached bird monitoring

Jan Seys[1*], Henk Offringa[2], Patrick Meire[3], Jeroen Van Waeyenberge[1] and Eckhart Kuijken[1]

[1] **Institute of Nature Conservation, Kliniekstraat 25, B-1070 Brussel, Belgium**
[2] **Ministry of Transport, Public Works and Water Management, Directorate General of Public Works and Water Management, North Sea Directorate, P.O.Box 5807, NL-2280 HV Rijswijk, The Netherlands**
[3] **University Antwerpen, Department Biology, Universiteitsplein 1, B-2610 Wilrijk, Belgium**

ABSTRACT. Trends in oil pollution in the southernmost (Belgian) part of the North Sea were analysed using a dataset of 37 years (1962-99) of annual national beached bird surveys conducted in February each year. The most abundant seabird groups represented in the beached birds were auks (31%), gulls (28%), scoters (17%) and Kittiwake (9%). Oil rates of most bird species/taxa indicate a decline in oil pollution, though only *Larus* -gulls, Common Guillemot and Razorbill show significant reductions. The slope in the linear decreasing trend is steeper in inshore and midshore species, than in pelagic species. A power analysis of the results demonstrated that statistically significant trends in annual indices would be expected within 17 years for Razorbill, 29 years for *Larus*-gulls and 31 years for Common Guillemot. For other species/taxa, at least 50 years of surveying would be required. Long-term oil pollution monitoring in Belgium should be continued with a major focus on a set of abundant bird taxa, sensitive to oil-pollution and occurring in various marine habitats. Most appropriate for this purpose are grebes (inshore), Larus-gulls, Common Guillemot and Razorbill (midshore) and Kittiwake and Fulmar (offshore).

KEY WORDS: seabirds, oil pollution, trends, North Sea, beached bird surveys, temporal variation.

INTRODUCTION

Seabirds are highly vulnerable to surface pollutants. The sporadic occurrence of large numbers of seabird corpses on North Sea beaches was noted over a century ago (Gray, 1871; Anonymous, 1876). The governments of North Sea countries endeavoured to stop the contamination of the marine environment by subscribing to international agreements (OILPOL, MARPOL 73/78 and Bonn 1983), in which they agreed to take measures for prevention and surveillance. Despite the execution of the accompanying laws (MARPOL was extended with an act of enforcement in Belgium in 1995), important numbers of oiled birds continued to wash ashore on North Sea beaches during the 1980s and early 1990s (Dunnet, 1987; Camphuysen, 1989; Christensen, 1989; Skov et al., 1989; Vauk et al., 1990; Heubeck et al., 1992, Raevel, unpublished data). As from 1 August 1999, the North Sea has been established as a Special Area under MARPOL Annex I (oil), meaning that every discharge of oil is illegal (Dahlmann, cited in Camphuysen & van Franeker, 1992). However, current estimates of illegal oil input in the North Sea range from 15,000 tonnes per year to as much as 60,000 tonnes (Peet, 1993), with oil slicks being not uncommon in the shipping corridor between the Straits of Dover and the German Bight (Ospar Commission, 2000).

Oil pollution at sea is basically monitored in two different ways. Beached bird surveying provides cost-effective and all-weather information on the occurrence of oil, while aerial surveillance gives accurate information on the location of oil slicks and the polluter. Beached bird surveying was acknowledged at the 4th International ministerial Conference on the Protection of the North Sea (8-9 June 1995) at Esbjerg (Denmark) as a useful

Corresponding author: J. Seys, e-mail: jans@vliz.be
[*] Present address: Flanders Marine Institute, Vismijn, Pakhuizen 45-52, B-8400 Oostende, Belgium.

oil-monitoring tool. In Belgium, aerial surveillance started in 1991 (JACQUES et al., 1991). In this short period of monitoring no trends could be discerned so far (SCHALLIER et al., 1996; DI MARCANTONIO, 1999). Beached bird surveying has a much longer tradition in Belgium, and the first standardized data go back as far as 1962. With Belgian data obtained at the annual International Beached Bird Surveys (IBBS) conducted in February each year from 1962-1999, we will investigate whether trends in densities and oil rates of sea- and coastal birds can be demonstrated. An investigation of oil rates in various species/taxa of seabirds can shed light on the impact of oil pollution in onshore versus offshore marine waters.

MATERIAL AND METHODS

Study area

The part of the sea under Belgian jurisdiction (further referred to as the Belgian marine waters) is heavily exploited by various users (MAES et al., 2000). Situated at the entrance of the Channel, this area is characterised by a very intensive and still increasing shipping traffic (OSPAR COMMISSION, 2000).

The Belgian shoreline has a length of 65.4 km (Fig. 1), of which 3.3 km is situated in between the moles of the outer harbour of Zeebrugge (constructed in 1974-86). Narrow, sandy beaches prevail, with broad beaches restricted to the west coast near De Panne (± 3 km) and at both sides of the Zeebrugge harbour piers (± 1 km). Groins are a characteristic feature at the Belgian shoreline (at every 300-500 m on average). More than half of the entire length of the coast (34 km) is bordered with buildings and boulevards (Fig. 1) and many beaches are frequently cleaned, particularly during summer. The prevailing wind direction in Oostende (compiled from meteorological data 1941-92) is S-SW (BELL, 1994).

History

In Belgium, the first occasional counts of beached birds go back as far as the 1950s and early 1960s (KESTELOOT, 1953; HAUTEKIET, 1955, 1956, 1961, 1965; DE RIDDER, 1961; HOUWEN, 1968). Counts of the entire Belgian coastline were coordinated by Kuijken from 1962 onwards and extended to substantial parts of the Dutch and northern French coasts in 1965 (BLANKENA & KUIJKEN, 1967). This was the earliest step towards the International Beached Bird Surveys (IBBS), at first supervised by Belgian and Dutch Youth Organisations for Nature Studies (BJN and NJN). Pioneers such as KUIJKEN & ZEGERS (1968), KUIJKEN (1978a, 1978b) and VERBOVEN (1978) published early reviews of time series on Belgian data. A period of centrally governed counts was concluded with counts coordinated by MEIRE (1978a,b). The eighties were characterised by many individual actions, instigated by several large seabird strandings (DE WAELE, 1981; VAN GOMPEL, 1981, 1984, 1987; VERBOVEN, 1985; SHERIDAN & PAMART, 1988). From the winter 1991-92 onwards, beached bird surveys were centralised again, this time by the Institute of Nature Conservation (SEYS & MEIRE, 1992). Since then, annual updates are available (SEYS & MEIRE, 1993; SEYS et al., 1993; OFFRINGA & MEIRE, 1995; OFFRINGA et al., 1995, 1997; SEYS et al., 1999).

Data collection and analysis

In many countries bordering the North Sea, the Channel, the Bay of Biscaya and the Baltic, annual beached bird surveys are organised in late February (IBBS), when high water marks are searched for beached bird corpses. The results – a list of birds, containing information on the distance covered and the number of oiled and clean birds – are included in an international database. For the study-period 1962-99, the Belgian IBBS database included a surveyed overall distance of 1976 km (Table 1) with major parts of the entire coastline covered during most years. No results for 1980 were available. Although the effort in 1981 was small, the results were considered not unreasonable and retained. Throughout the entire study period the coastal villages and towns served as boundaries for different beach sections (Fig. 1). Despite the expected strong coherence among the relatively short and close sections, local differences in strandings existed (SEYS et al., 1993; OFFRINGA et al., 1995). In years with incomplete coverage, surveys were biased to specific beach stretches (1980s), so a correction factor for every

TABLE 1

Effort and total number of beached birds during IBB in Belgium, 1962-99.

Species/taxon	1960s	1970s	1980s	1990s	1962-99
divers	79	29	8	8	124
grebes	99	144	34	53	330
Fulmar	122	18	19	109	268
Northern Gannet	49	15	3	4	71
Cormorant/Shag	1	0	1	0	2
Eider	11	2	3	7	23
scoters	636	177	39	35	887
other seaducks	1	2	1	5	9
other wildfowl	41	70	5	23	139
Coot	151	190	4	3	348
waders	63	103	24	264	454
skuas	3	1	1	0	5
Larus-gulls	751	475	83	156	1465
Kittiwake	212	75	91	72	450
auks total	535	205	209	692	1641
Common Guillemot	282	69	147	588	1086
Razorbill	245	135	60	96	536
others	234	141	29	123	527
Effort (km)	502.6	644	252.5	576.4	1975.5

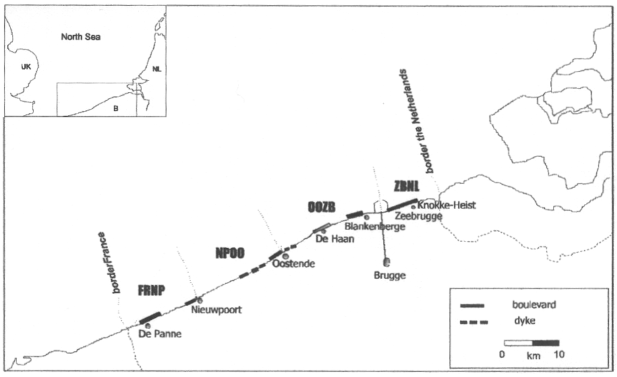

Fig. 1. – Study-area showing the boundaries of the beach sections used in Belgian beached bird surveys.

section was calculated by comparing the section density with the mean density of the entire Belgian coast ($d_{coast}/d_{transect}$). The factors are mean values of 20 years IBBS in Belgium, in which all sections were covered (Table 2). These correction-factors were applied to densities in years with incomplete coverage, when the average of the factors was taken of corresponding (combinations of) beach sections.

TABLE 2

Correction factors for Belgian beach sections, based on 20 complete IBB surveys during 1962-99.

Beach section		correction factor
French border - Nieuwpoort	(FRNP)	0.69
Nieuwpoort - Oostende	(NPOO)	1.14
Oostende - Zeebrugge	(OOZB)	0.90
Zeebrugge - Dutch border	(ZBNL)	2.14

Grouping of species in taxa roughly followed STOWE (unpublished data) and CAMPHUYSEN (1989). We focussed on birds that occupy different habitats and are unequally vulnerable for oil pollution: divers (Red-throated Diver *Gavia stellata* Pontoppidan, 1763, and Black-throated Diver *G.arctica* L., 1758), grebes (Great-crested Grebe *Podiceps cristatus* L., 1758), Fulmar (*Fulmarus glacialis* L., 1761), Northern Gannet (*Morus bassanus* L., 1758), Eider (*Somateria mollissima* L., 1758), scoters (Common Scoter *Melanitta nigra* L., 1758, and Velvet Scoter *M. fusca* L., 1758), Coot (*Fulica atra* L., 1758), waders, skuas (Great Skua *Skua skua* Brünnich, 1764, Pomarine Skua *S. pomarinus* Temminck, 1858, Arctic Skua *S.parasiticus* L., 1758), *Larus*-gulls L., Kittiwake (*Rissa tridactyla* L., 1758), Common Guillemot (*Uria aalge* Pontoppidan, 1763) and Razorbill (*Alca torda* L., 1758). Total numbers are of little value when comparing years with different effort, change in environmental conditions, etc. This was accounted for by using 'number/km' (density), and 'oil rate' (the proportion of complete bird corpses with oil: $n_{oiled}/n_{all\ birds} * 100\%$). The latter is widely accepted as a good indicator of oil pollution (SKOV, 1991; CAMPHUYSEN, 1993, 1995, 1998) and is presumably only influenced by post-mortem contamination and rejection by scavengers. Oil rates were not calculated when less than ten complete bird corpses were available (SKOV et al., 1996). Trends in oil rates were calculated after logit-transformation of the data by means of linear regression (by least-squares estimation). The probability that a trend, if present, will be detected as statistically significant, was studied by means of a power analysis (CAMPHUYSEN, 1995).

RESULTS

Overall trend in density and oil rate of beached birds

The total (non-corrected) numbers, effort and oil rates are summarized in Tables 1 and 3.

A total of 6743 birds of 80 different species have been recorded at Belgian IBB surveys during 1962-99. The Shannon-Wiener diversity index decreased significantly over the years (Kendall τ = -0.285, N = 37, P < 0.05), whilst the effort did not go down significantly (τ = -0.221, N = 37, P = 0.051). The total density of beached birds did not change during the study-period (R^2 = 0.041, *rms* = 11.7, b = -0.06, N = 37, P = 0.23). However, four discrete periods can be demonstrated, coinciding more or less with the four decades (Fig. 2). The 1960s were characterised by high overall densities (average 5.7, s.d. 1.9, birds/km) and high oil rates (average 73.2, s.d. 15.0,%). In the 1970s, the situation had changed dramatically (2.1, s.d. 2.2, birds/km and 51.0, s.d. 27.1,%), but by the end of that decade numbers increased again. The agony of the sixties was repeated in the 1980s, but now the birds came in pulses (2.8, s.d. 2.0, birds/km and 62.8, s.d. 19.2,%). The densities were slightly reduced again in the 1990s (2.6, s.d. 2.1, birds/km) and oil rates markedly declined (44.7, s.d. 20.8,%). Over the entire study-period, oil-rates showed a downward slope for all species/taxa except one

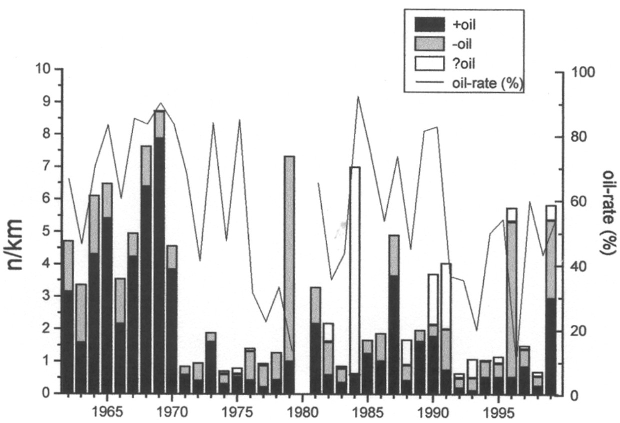

Fig. 2. – Densities (bars) and oil rates (line) of all beached birds collected during IBB surveys in Belgium during 1962-99. Densities are subdivided into 'oiled', 'unoiled' and 'not scored' specimens.

(Kittiwake). Scoters and *Larus*-gulls were most abundant as beached birds during the 1960s; Kittiwake and Common Guillemot were particularly common in the 1980s (and 1990s for the Common Guillemot).

Onshore versus offshore bird taxa

Larus-gulls, Northern Gannet, scoters and divers significantly decreased in densities at IBB surveys during 1962-99. The Common Guillemot is the only common species that became significantly more abundant during the study-period (Table 3). Taxa or species that do not show significant trends appear to be either offshore species (Fulmar, Kittiwake, skuas) or birds known to be sensitive to cold winter weather (Coot, grebes, waders).

Oil rates of a typical offshore species, the Kittiwake, did not change significantly during the 37 years of study (Table 3, Fig. 3). Two groups of birds that are very common at 10-30 km from the coast, the *Larus*-gulls and the Common Guillemot, show significant declines in oil rate. The oiling among gulls was heaviest in the 1960s (69%) and decreased to 20% in the 1990s. The average oil rate in the Common Guillemot was higher, both in the 1960s (99%) and in the 1990s (61%). The decline in oil rate in the Razorbill – a species occurring in the same wintering areas as the Common Guillemot – was less pronounced but still significant (1960s: 98%, 1990s: 64%). Inshore and coastal species all show lower oil rates now than some forty years ago, though none of the trends was significant (Table 3). That this should be attributed to the sample size, being too small to reveal trends, can be demonstrated with a power analysis. For waders, grebes and scoters we need at least 50 years of surveying to get a 90% probability to find an existing trend (Fig. 4). Only for Razorbill (17 years), *Larus*-gulls (29 years) and Common Guillemot (31 years), were the IBB surveys able to produce significant trends at this probability.

TABLE 3

Trends in (a) densities (n/km) and (b) logit-transformed oil rates of the most important sea- and coastal bird species/taxa at the Belgian coast during the winters of 1962-99. Shown are mean values of densities and non-transformed oil rates by decade and linear trends (rms = residual variance; b = slope of regression; R^2; n = number of winters; significance: n.s. = non significant, *= P < 0.05, ** = P < 0.01, *** = P < 0.001). Notice that the numbers of skuas were too low to calculate trends in oil-rate.

(a)	**Density (n/km) by decade**				**trend**				
Species/taxon	60s	70s	80s	90s	*rms*	slope *b*	R^2	*n*	*P*
divers	0.19	0.05	0.05	0.03	0.008	-0.004	0.228	37	**
grebes	0.19	0.17	0.27	0.10	0.053	-0.003	0.020	37	n.s.
Fulmar	0.31	0.04	0.13	0.23	0.118	-0.001	0.002	37	n.s.
Northern Gannet	0.11	0.03	0.05	0.02	0.002	-0.002	0.276	37	***
scoters	1.23	0.22	0.21	0.08	0.411	-0.029	0.212	37	**
Coot	0.33	0.33	0.08	0.02	0.249	-0.009	0.040	37	n.s.
waders	0.12	0.17	0.21	0.57	0.312	0.011	0.045	37	n.s.
skuas	0.02	0.02	0.03	0.00	0.000	-0.000	0.075	37	n.s.
Larus-gulls	1.52	0.65	0.44	0.29	0.444	-0.035	0.268	37	**
Kittiwake	0.42	0.11	0.54	0.16	0.189	-0.004	0.009	37	n.s.
Common Guillemot	0.56	0.10	0.78	1.00	0.456	0.021	0.110	37	*
Razorbill	0.48	0.20	0.32	0.18	0.136	-0.009	0.074	37	n.s.

(b)	**Oil rate (%) by decade**				**trend**				
Species/taxon	60s	70s	80s	90s	*rms*	slope *b*	R^2	*n*	*P*
divers	99	93	50	-	-	-	-	2	-
grebes	88	55	76	42	0.755	-0.043	0.305	10	n.s.
Fulmar	53	75	40	45	-	-	-	2	-
Northern Gannet	99	75	-	-	-	-	-	2	-
scoters	89	71	83	55	0.746	-0.051	0.153	13	n.s.
Coot	47	3	-	-	0.079	-0.100	0.902	4	n.s.
waders	18	10	0	1	0.088	-0.005	0.082	5	n.s.
Larus-gulls	69	41	22	20	0.315	-0.037	0.318	24	**
Kittiwake	76	59	93	62	0.527	0.020	0.105	12	n.s.
Common Guillemot	99	84	82	61	0.474	-0.051	0.492	23	***
Razorbill	98	88	92	64	0.163	-0.034	0.521	11	*

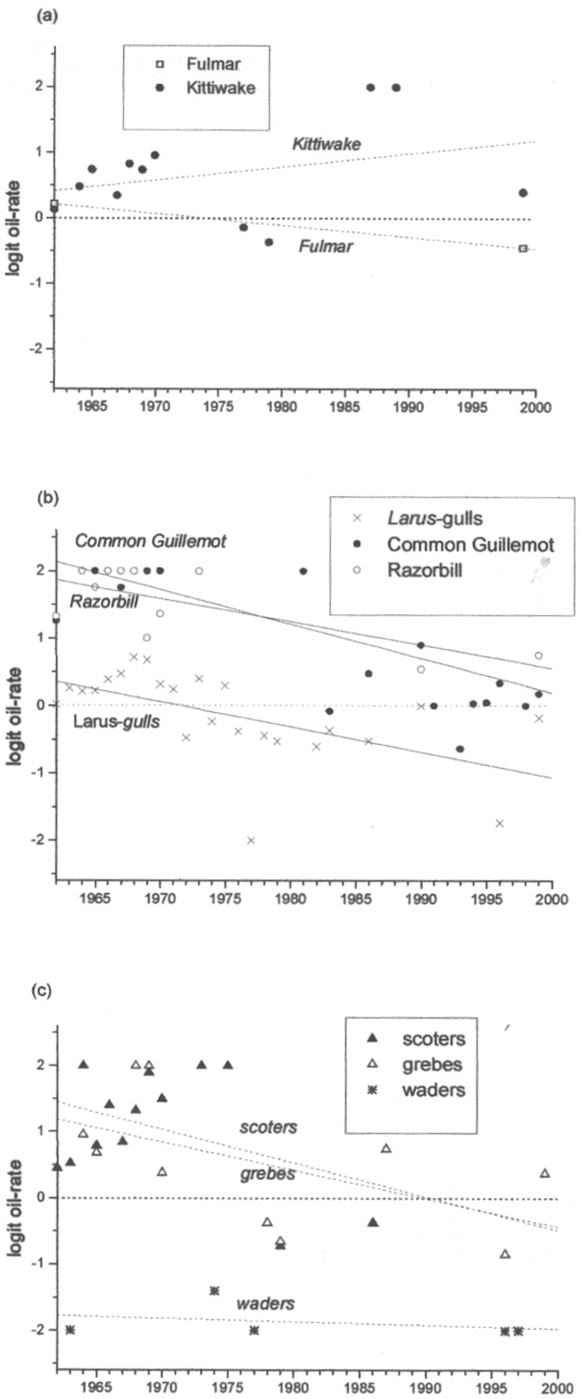

Fig. 3. – Trends in oil rate of seabird groups in Belgium based on results of February IBB surveys during 1962-99. Trends for an offshore (a), midshore (b) and inshore group of species are shown (see also Table 5). Significant trends are in solid line, others in dashed line.

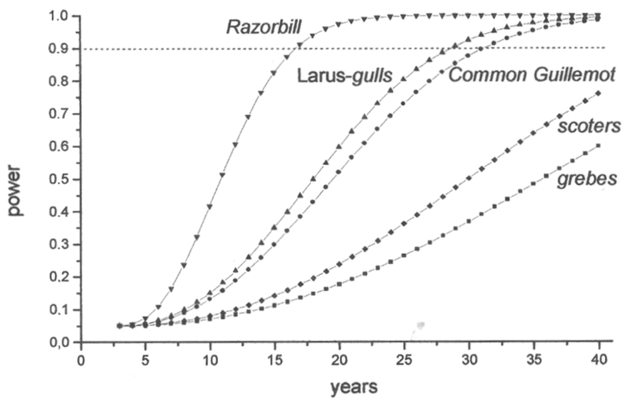

Fig. 4. – Power of trend test of oil-rates in seabird species/taxa versus number of years sampled based on IBB surveys at the Belgian coast in February during 1962-99.

DISCUSSION

Quality of the data

In IBB surveys during the 1980s the Belgian beaches were not completely covered. Hence, geographical differences may influence the outcome of the survey. Raevel (unpublished data) demonstrated that a minimum of 25-30% of the (Nord-Pas-de-Calais to Picardie) coastline must be surveyed to get reliable densities and oil rates for the whole coast. Accordingly Seys et al. (2002) found oil rates of Common Guillemot to stabilize above a sample of 10-15 bird corpses, a figure corresponding to a mean surveyed distance of 25-30 km (or 40-50% of the entire Belgian coast). More than half of the coast, some 65%, (Raevel, unpublished data; Seys et al., 2002) must be covered to approach the actual species richness. These figures underscore the necessity to put substantial effort into the beach surveys. This effort is normally met in Belgian BBS, but the results of years with low effort (1981, 1984, 1985, 1987) are put into question.

Oil pollution trends in the North Sea

In many countries bordering the North Sea, long-term trends in oil pollution have been described, as derived from the proportion of beached birds with oil (Stowe, unpublished data; Averbeck et al., 1992; Heubeck, 1995; Skov et al., 1996; Fleet & Reineking, 2000; Camphuysen & Heubeck, 2001). Measurable declines have been observed in several species along the north-east English and Scottish coasts, in south-east England, in parts of Denmark (see Skov et al., 1996), in the Netherlands (Camphuysen, 1998; Camphuysen & Heubeck, 2001) and in Germany (Averbeck et al., 1992; Fleet & Reineking, 2000). The Belgium coast borders the southernmost part of the North Sea, an area heavily affected by chronic oil pollution (North Sea Task Force, 1993, Ospar Commission, 2000). Our data show downward trends in oil rate for most species, trends that are highly significant for only the two most abundant taxa (Common Guillemot, *Larus*-gulls).

Stowe (unpublished data) and Skov et al. (1996) showed that in the countries around the Southern Bight, the proportions of oiled Common Guillemots – an important target species – were higher than in other West European countries. That the proportion of oiled Common Guillemots in the late 1980s and early 1990s in Belgium is relatively low (approximately 50%) compared to surrounding countries (more than 75%; CAMPHUYSEN, 1995) can partly be attributed to a different approach: CAMPHUYSEN (1995) considered data collected on Dutch beaches during ten winters (1985/86-1994/95) and used extensive material of six monthly surveys for each winter. For Belgian beaches however, only data from IBB February surveys (1986-95) (SKOV et al., 1989; SKOV, 1991) and additional information from January 1992 up to March 1995 were used (SEYS & MEIRE, 1992, 1993; OFFRINGA & MEIRE, 1995; OFFRINGA et al., 1995). While there were several wrecks in the early 1990s that were important with regard to the Common Guillemot, low proportions of bird corpses oiled resulted in overall oil rates being lowered quite drastically. When all existing Common Guillemot data from Belgian beaches (i.e. including monthly and weekly winter surveys) are used, a mean oil rate of 65% for the period 1986-95 is found, a value intermediate between the 50% mentioned above and the 75% recorded on Dutch beaches.

In our data, offshore species such as Fulmar and Kittiwake do not show significant changes in oiling. These species occur around the offshore shipping lanes, where most oil slicks were recorded over the past eight years (DI MARCANTONIO, 1999; SCHALLIER et al., 1996;). Both species are not considered particularly vulnerable for oil since they spend much time on the wing. Nevertheless it is surprising that no downward trend can be discerned as found in the Netherlands, Germany, England and Scotland in the period 1984-95 (CAMPHUYSEN, 1995; SKOV et al., 1996). The smaller slope in the downward trend (Fig. 3) – as found in the Netherlands as well (CAMPHUYSEN, 1998) – probably explains why the trend is not (yet) significant for the Fulmar. The same applies to waders. They were often found oiled during the 1960s (indicating the beaching of oil slicks or post-mortem contamination) but now clearly have a smaller risk of becoming oil-fouled. That we do not find significant downward trends in oil rate yet, must be ascribed to the relatively slow decrease and hence the need for a higher number of sampling years (58 years to have a power of 90%). The very low numbers of seaducks beaching these days in combination with the exceedingly high number of surveying years needed to find a trend, necessitates the focus on the most common taxa (auks, *Larus*-gulls) and the collection of additional data during the rest of the winter. The slopes of the linear regression in various species confirm the general pattern of oil rates for offshore birds decreasing less quickly than for inshore and midshore species. It can be concluded that densities of most beached bird species are much smaller now than in the past, and that oil rates show consistent declines more prominent in coastal birds than in pelagic species.

Target species for oil monitoring

Future research should focus on several species and/or groups of species simultaneously to avoid problems caused by certain mortality incidents in individual species and to sample different subregions (inshore vs. offshore). For The Netherlands, CAMPHUYSEN (1995) selected Common Guillemot, Razorbill, Kittiwake, Fulmar, Northern Gannet, scoters and *Larus*-gulls as target species for beached bird surveying. A power analysis on Dutch data reveals that trends should be demonstrable – even for species showing linear trends with high residual variance and small slope – within 13-17 years. The trends we find by using only IBB surveys have a much lower power, meaning that at least some 30 years are needed before an existing trend will be detected with a chance of 90%. Considering the small length of the Belgian coastline and hence the comparatively small total number of beached birds that can be collected at each February IBB survey, oil impact monitoring should: (1) collect as many corpses and species as possible, and group species typical for each of the different marine habitats (inshore, midshore, offshore) for further analysis; (2) always be organised synchronic with counts in neighbouring countries; (3) be complemented with monthly surveys at least during winter.

In designing future beached bird surveys, one of the main considerations in relation to analysing trends in the proportion of oiled corpses, should be the limited number of beached birds (SKOV et al., 1996). Due to decreasing densities of beaching corpses, it might become more and more difficult to collect large enough samples (and keep the numerous volunteers motivated). Assuming that a sample of at least ten complete corpses is required to calculate reliable oil rates, only the Common Guillemot (as species) and auks (as taxon) can provide the necessary data in Belgium these days. The beach environment and adjacent surf zone can probably be monitored much better during winter by scoring oil rates on live birds, such as Sanderlings *Calidris alba* Pallas, 1764 (a small wader, pale in colour and constantly foraging near the water mark). For the inshore zone, the most suitable potential target species is the Great-crested Grebe (common in February in inshore waters), for the midshore area the Common Guillemot, Razorbill and several *Larus*-gull species can fulfil the role of oil indicators. For the offshore zone probably only Kittiwake and Fulmar would be suitable. Although the IBB surveys may have some drawbacks compared to repeated monthly or weekly beached bird surveys (SEYS et al., 2002) they provide invaluable information, and can build on large historical datasets collected in a standardized way over a vast area and hence should be continued and strengthened in the future.

ACKNOWLEDGEMENTS

The cooperation with a large number of volunteers – too many to mention them all by name – is crucial in the realisation of most beached bird surveying programs. Without their help, the present analysis would never have got off the ground. Since 1992 the BBS study has been financed successively by the Worldwide Fund for Nature (WWF), the Management Unit for the Mathematical Model of the North Sea (MUMM) and the Federal Services for Scientific, Technical and Cultural Affairs (DWTC). We would like to acknowledge all participants to the Marine mammals and seabird Research and Intervention Network (MARIN) for their cooperation since 1992. Jan Haelters and Thierry Jacques (MUMM) provided extra information on the role of Belgium in combatting oil pollution and gave particularly meaningful comments on an earlier version. Kees Camphuysen is thanked for his advice and provision of several 'difficult to spot' publications. Tom Ysebaert, Steven Van Tieghem and Stephan Van Dongen assisted in the statistical analysis of the data. Bart and Piet Opstaele, Dries Bonte, Dirk Vanhoecke, Filip de Ruwe, Frederik Willemeyns, Guido Rappé, John Van Gompel, Jozef Vansteenkiste, Paul Lingier, Patrick Lust, Pascal Raevel and Tim Adriaens provided additional data collected during the '80s and early '90s.

REFERENCES

ANONYMOUS (1876). *Proc. Nat. Hist. Soc. Glasgow,* 2: 181-182.

AVERBECK, C., M. KORSCH & G. VAUK (1992). Der Einfluss von Ölverschmutzungen auf Seevögel an den deutsche Nordseeküsten van 1984 bis 1990. *Seevögel,* 13, 12-16.

BELL, P. (1994). *Dover Strait Pilot*, third edition. Hydrographic Office, Somerset, UK.

BLANKENA, G. & E. KUIJKEN (1967). Stookpietenverslag 1967. *Amoeba,* 43: 121-128.

CAMPHUYSEN, C.J. (1989). *Beached Bird Surveys in the Netherlands 1915-1988: Seabird Mortality in the southern North Sea since the early days of Oil Pollution*. Technisch Rapport Vogelbescherming 1. Werkgroep Noordzee. Amsterdam: 322pp.

CAMPHUYSEN, C.J. (1993). Zeevogelstrandingen op de Nederlandse kust: 26 jaar een vinger aan de pols (1965-91). *Limosa,* 66: 1-16.

CAMPHUYSEN, C.J. (1995). Olieslachtoffers langs de Nederlandse kust als indicatoren van de vervuiling van de zee met olie. *Sula,* 9 (special issue): 1-90.

CAMPHUYSEN, C.J. (1998). Beached bird surveys indicate decline in chronic oil pollution in the North Sea. *Mar. Poll. Bull.*, 36 (7): 519-526.

CAMPHUYSEN, C. J. & VAN FRANEKER, J.A. (1992) *The value of beached bird surveys in monitoring marine oil pollution*. Zeist, Vogelbescherming Nederland.

CAMPHUYSEN, C.J. & M. HEUBECK (2001). Marine oil pollution and beached bird surveys: the development of a sensitive monitoring instrument. *Environmental Pollution* 112: 443-461.

CHRISTENSEN, K.D. (1989). *Beached Birds Survey. Monitoring the Effects of Oil Pollution on Birds*. Report ECComm. Ornis Consult/ Dan. Orn. Soc., Copenhagen.

DE RIDDER, M. (1961). Victimes ailées du mazout. *Naturalistes Belges*, 42: 145-156.

DE WAELE, G. (1981). Olieslachtoffers. *Veldornith. Tijdschrift*, 4: 35-36.

DI MARCANTONIO, M. (1999). *Toezicht op de Noordzee vanuit de lucht: resultaten van het Belgisch programma*. Activiteitenrapport 1996-1998. Report BMM: 55p.

DUNNET, G.M. (1987). *Seabirds and North Sea oil*. Phil. Trans. R. Soc., London. B.

FLEET, D.M. & B. REINEKING (2000). Beached Bird Surveys at the German North Sea Coast. *Wadden Sea Newsletter*, 2: 26-28.

GRAY, R. (1871). *Birds of West-Scotland*. Murray, Glasgow.

HAUTEKIET, M.R. (1955). Vijf jaar stookolieslachtoffers. *Wielewaal*, 11: 289-294.

HAUTEKIET, M.R. (1956). Winterslachtoffers. *Wielewaal*, 22: 141-145.

HAUTEKIET, M.R. (1961). Wintervogels van het strand. *Wielewaal*, 27: 2-6.

HAUTEKIET, M.R. (1965). Vogels tijdens strenge winters. *Wielewaal*, 31: 33-40.

HEUBECK, M. (1995). *Shetland beached bird surveys: national and European context*. In: Proceedings of the Royal Society of Edinburgh. 103B, 165-179. 1995.

HEUBECK, M., E. MEEK & D. SUDDABY (1992). The occurrence of dead auks Alcidae on beaches in Orkney and Shetland, 1976-1991. *Sula* 6: 1-18.

HOUWEN, P.J. (1968). Dénombrement des oiseaux échoues sur une portion de la côte Belge pendant l'hiver. *Aves* 5: 170-177.

JACQUES, T.G., A. VAN DER ELST & L. LAHOUSSE (1991). *Programma van toezicht vanuit de lucht. Periode van 1 juli 1990 tot 30 juni 1991*. Beheerseenheid van het Mathematisch Model van de Noordzee en Schelde-estuarium, Brussel.

KESTELOOT, E. (1953). Objecten voor biologische wandelingen: stookolieslachtoffers langs de kust. *Club van leraars in de Wetenschappen*, 1: 1-4.

KUIJKEN, E. (1978a). Resultaten van 15 jaar stookolieslachtoffertellingen in België. *Porzana*, 5: 38-39.

KUIJKEN, E. (1978b). Beached bird surveys in Belgium. *Ibis*, 120: 122-123.

KUIJKEN, E. & P.M. ZEGERS (1968). De stookpietentelling 1968. *Amoeba*, 44: 154-158.

MAES, F., A. CLIQUET, J. SEYS, H. OFFRINGA & P. MEIRE (2000). *A limited atlas of the Belgian part of the North Sea*. DWTC, Maritime Institute, Institute of Nature Conservation.

MEIRE, P. (1978a). Verslag Stookolietelling 1976. *Porzana*, 5: 4-8.

MEIRE, P. (1978b). Verslag Stookolietelling 1977. *Porzana*, 5: 9-19.

NORTH SEA TASK FORCE (1993). *North Sea Quality Status Report 1993*. Oslo and Paris Commissions. London 1993.

OFFRINGA, H. & MEIRE, P. (1995). *Tellingen van gestrande zeevogels langs de Vlaamse kust, november 1994 -maart 1995*. Rapport IN 95.13. Instituut voor Natuurbehoud, Hasselt.

OFFRINGA, H., P. MEIRE & W. VAN DEN BOSSCHE (1995). *Tellingen van gestrande zeevogels langs de Vlaamse kust, november 1993 - maart 1994*. Rapport IN 95.5. Instituut voor Natuurbehoud, Hasselt.

OFFRINGA, H., R. SCHALLIER, T. JAUNIAUX, J. HAELTERS & P. MEIRE (1997). Olieverontreiniging op de Noordzee: gevolgen voor de zeevogels (november 1995-maart 1996). *Mergus,* 11: 25-45.

OSPAR COMMISSION (2000). *Quality Status Report 2000, Region II – Greater North Sea*. OSPAR Commission, London. 136 + xiii pp.

Peet, G. (1993). Oil spilt in the marine environment: how big is the problem? *North Sea Monitor*, 3-6.

Schallier, R., L. Lahousse & T. Jacques (1996). *Toezicht vanuit de lucht: Zeeverontreiniging door schepen in de Belgische Belangenzone van de Noordzee – Activiteiten rapport 1995*. Rapport BMM. Beheerseenheid Mathematisch Model Noordzee en Schelde, Brussel.

Seys, J. & P. Meire (1992). *Resultaten Stookolieslachtoffer-tellingen langs de Vlaamse kust in de periode januari-april 1992*. Rapport A92.084. Instituut voor Natuurbehoud, Hasselt.

Seys, J. & P. Meire (1993). Olieslachtoffertellingen langs de Belgische kust, winter 1991-92. *Sula*, 7: 15-19.

Seys, J., P. Meire & E. Kuijken (1993). *Resultaten van stookolieslachtoffer-onderzoek langs de Vlaamse kust tijdens de winter 1992-93*. Rapport 93.15. Instituut voor Natuurbehoud, Hasselt.

Seys, J., J. Van Waeyenberge, P. Meire & E. Kuijken (1999). *Massale stranding van vogels aan de Belgische kust in februari 1999*. Nota IN A57: 10pp.

Seys, J., H. Offringa, J. Van Waeyenberge, P. Meire & E. Kuijken (2002). An elevation of beached bird monitoring approaches. *Mar. Poll. Bull*., 44: 322-333.

Sheridan, R. & L. Pamart (1988). Analyse de l'échouage et des causes de mortalité d'oiseaux marins récoltés sur la côte Belge entre avril 1986 et mars 1987. *Aves*, 25: 153-170.

Skov, H. (1991). Trends in oil contamination of seabirds in the North Sea. *Sula* 5 (special issue): 22-23.

Skov, H., F. Danielsen & J. Durinck (1989). Dead Seabirds along European coasts, 1987 and 1988. *Sula*, 3: 9-19.

Skov, H., K.D. Christensen & J. Durinck (1996). *Trends in marine oil pollution in Denmark 1984-1995*. Working report 75. Ministry of Environment and Energy, Denmark.

Van Gompel, J. (1981). De massale zeevogelsterfte aan de Belgische kust tijdens de voorbije winter. *Wielewaal*, 47: 137-142.

Van Gompel, J. (1984). Opnieuw massale zeevogelsterfte aan onze kust tijdens de winter 1982-1983. *Wielewaal*, 50: 150-155.

Van Gompel, J. (1987). Mortaliteit van waadvogels in een overwinteringsgebied aan de Belgische kust tijdens de koudeperiode januari-februari 1985. *Oriolus*, 53: 175-186.

Vauk, G., E. Hartwig, B. Reineking, E. Schrey & E. Vauk-Hentzelt (1990). Langzeituntersuchung zur Auswirkung der Ölverschmutzung der deutschen Nordseeküste auf Seevögel. *Seevögel* 11: 17-20.

Verboven, J. (1978). Problemen die opduiken bij een stookpieten onderzoek. *Porzana*: 31-37.

Verboven, J. (1985). Stookolieslachtoffers aan de Belgische kust gedurende de winter 1983-1984. *Wielewaal*, 51: 2-9.

Received: August 8, 2001
Accepted: March 27, 2002