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An evaluation of beached bird monitoring approaches

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Abstract

Oil-pollution monitoring at sea through beach bird surveying would undoubtedly benefit from a further standardisation of methods, enhancing the efficiency of data collection. In order to come up with useful recommendations, we evaluated various approaches of beached bird collection at the Belgian coast during seven winters (1993–1999). Data received in a passive way by one major rehabilitation centre were compared to the results of targeted beach surveys carried out at different scales by trained ornithologists: 'weekly' surveys – with a mean interval of 9 days – restricted to a fixed 16.7 km beach stretch, 'monthly' surveys over the entire coastline (62.1 km) and an annual 'international' survey in Belgium over the same distance at the end of February. Data collected through Belgian rehabilitation centres concern injured, living birds collected in a non-systematical way. Oil rates derived from these centres appear to be strongly biased to oiled auks and inshore bird species, and are hence of little use in assessing the extent of oil pollution at sea. The major asset of rehabilitation centres in terms of data collection seems to be their continuous warning function for events of mass mortality. Weekly surveys on a representative and large enough section rendered reliable data on oil rates, estimates of total number of bird victims, representation of various taxonomic groups and species-richness and were most sensitive in detecting events quickly (wrecks, oil-slicks, severe winter mortality, etc.). Monthly surveys gave comparable results, although they overlooked some important beaching events and demonstrated slightly higher oil rates, probably due to the higher chance to miss short-lasting wrecks of auks. Since the monthly surveys in Belgium were carried out by a network of volunteers and were spread over a larger beach section, they should be considered as best performing. Single 'international beached bird surveys' in February gave reliable data on total victim number (once the mean ratio between numbers in various months is known) and oil rate (provided a sufficiently large sample can be collected), but failed in tracking events. It is a particularly attractive approach because of its long tradition, resulting in invaluable long-term databases, and the uniformity in which these surveys are organised on a large scale. The minimal distance for a monthly survey amounts to 25–30 km (40–50% of Belgian coastline) up to 40 km (65%) in order to attain sound figures for oil rate and species-richness, respectively. These distances are primarily determined by the number of bird corpses that may be collected and are hence a function of beaching intensity and corpse detection rate.

Keywords: Seabirds; Oil pollution; North sea; Beached bird surveys; Rehabilitation centre; Methodology

1. Introduction

Beached bird surveys have been set up worldwide to establish the patterns of occurrence of dead seabirds along coastlines and the proportions of the different species that are oiled (Camphuysen and Heubeck, 2001). It is a rather cost-effective method that allows demonstrating long-term changes in oil-pollution (Averbeck et al., 1992; Meissner, 1992; Camphuysen, 1998), to evaluate changes in policy (Averbeck, 1991; Heubeck, 1995) or to assess the scale of oiling incidents (Bourne et al., 1967; Jones et al., 1970; Bourne, 1979; Piatt et al., 1990; Heubeck et al., 1995; Camphuysen, 1996). However, due to an overall lack in structural funding and a reliance on volunteers, beached bird surveying has been subject to large temporal and spatial fluctuations. The

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frequency and survey distance often differ considerably in time and from country to country, ranging from an effort restricted to single occasions on only a few sections up to full monthly coverage of entire coastlines (Heubeck and Camphuysen, 1992).

It is widely accepted that beached bird surveying should be designed according to an internationally harmonised standard methodology, as to enable comparisons between countries, continents, seasons and years (Camphuysen and van Franeker, 1992). Although several manuals and papers indicate how to organise beached bird monitoring in order to obtain reliable data at minimal cost and effort (Ainley et al., 1980; Jones et al., 1982; Page et al., 1982; Powlesland and Imber, 1988; Christensen, 1989; Camphuysen and Dahlmann, 1995; Camphuysen, 1999), very little has been published to underpin these suggestions (Camphuysen, 1991a; Raevel, 1992a,b,c). The minimal requirements are that it provides: (1) reliable oil rates for target species and; (2) estimates of densities and/or minimal total numbers of birds washed ashore (particularly in oil incidents). The value of the program further improves when: (3) it helps detecting specific short as well as longlasting events (wrecks, severe frost, oil incidents); (4) it provides a large and varied sample of bird corpses, that can be used for an additional postmortem necropsy (Stephen and Burger, 1994), drift-, sink- or persistence experiments or the analysis of contaminants in body (Debacker et al., 2000) or feathers (Dahlmann et al., 1994). A scheme of monthly sampling of the abundance of beached birds and the percentage of these birds which are oiled, at least in the winter period (i.e. October–April) has been put forward. Counts should be made on a selected, representative fraction of the coast, providing a sufficiently large sample of beached birds of the most common species, that enables the calculation of reliable oil rates (Camphuysen and Heubeck, 2001). As a rule of thumb, it has been suggested that all dead beached birds should be recorded over at least 10% of the coastline of each subregion (Camphuysen and Dahlmann, 1995).

Over the past 30 years beached bird surveys have been particularly intense in Britain, Belgium, The Netherlands, Germany and France (Camphuysen and Heubeck, 2001). A constant and high survey effort on 65 km of sandy beach in Belgium during the winters of 1993–1999 provides data for a critical analysis of various monitoring approaches. Data of beached birds collected at one major rehabilitation centre and on the beach during weekly, monthly and annual February surveys are compared. Furthermore we look into the impact of the sampling effort (distance, frequency) and the method (rehabilitation centre versus beached bird surveys) on oil rate, species composition and total number of beached birds and try to answer questions such as: 'How frequent does one have to survey in order to avoid unacceptable deviations in the variables mentioned above?', 'What is the minimal distance that should be surveyed?', 'Is distance determining the quality of the resulting data or other dependent parameters?', 'How can rehabilitation centres contribute to beached bird data collection?' Finally current guidelines for beached bird surveying are evaluated and recommendations are made – under the precondition of an acceptable data quality – for a minimal cost, maximal output programme.

2. Study area and methods

2.1. Study area and study period

The Belgian coastal strip consists of 62.1 km of easily accessible, sandy beach that is only interrupted at Zeebrugge port (Fig. 1). Four major beach sections are distinguished for further analysis: French border–Nieuwpoort (FRNP), Nieuwpoort–Oostende (NPOO), Oostende–Zeebrugge (OOZB) and Zeebrugge–Dutch border (ZBNL). Groins are a common feature (on average every 200–400 m) and are only absent at the west coast (FRNP), at Bredene–De Haan and near the Belgian–Dutch border. The tidal amplitude measures 3–5 m and beaches are generally narrow. Broad beaches are restricted to the western part (De Panne: ±3 km) and the immediate neighbourhood of Zeebrugge port (±1 km). Currents are predominantly oriented parallel to the coast and attain maximal velocities of 1.7 knots at spring tide and 0.6 knots at neap tide. There is a small net residual NE-circulation through the Straits of Dover. The prevailing wind direction in Oostende is S or SW (Bell, 1994). During persistent westerly gales, the velocity of surface water can be as high as 35 miles within 24 h.

During the study period 1993–1999, winters were not particularly cold, with severe frost restricted to early 1996 and 1997, and a short cold spell at the end of December 1992. Frequency of strong onshore winds was high in 1994 and 1995 and low in 1996 and 1997.

2.2. Beached bird survey approaches

Four different approaches were compared. Rehabilitation centres received debilitated or moribund, live birds in a mostly passive and continuous way. During beached bird surveys, trained ornithologists collected bird corpses on the beach, identified and measured them and checked the complete corpses on the presence of oil. Bird corpses obtained from the harbour area of Zeebrugge or during occasional surveys (organised in the wake of claimed incidents or massive beaching of corpses) were excluded from the analysis.

A 16.7 km section (NPOO) has been surveyed 'weekly' (i.e. with an average interval of 9 days) from

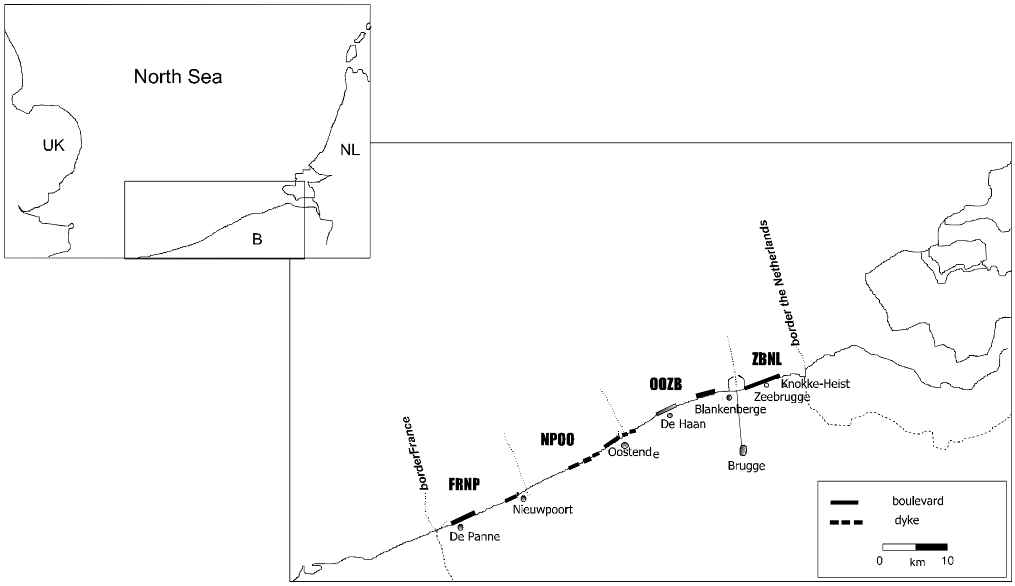

Fig. 1. The Belgian coast divided in four major beach sections.

mid-October to the end of March. In addition the entire Belgian coast (62.1 km) has been surveyed monthly from October to March, with only poor coverage in October 1992–1994 (Table 1). The results of the February surveys counted as International Beached Bird surveys (IBBS).

The data collected during beached bird surveys were compared to information on debilitated or moribund, live birds received at the Marine Ecological Centre (MEC) at Oostende from October 1992 till end March 1999. This rehabilitation centre proved to maintain the most detailed casualty lists, accommodates about 40% of the rehabilitated birds of the Belgian coast (Seys et al., 1999) and is centrally located, adjacent to the weekly surveyed beach section. Most birds received at the MEC rehabilitation centre were collected on the beach section Westende-De Haan. Hence for further analysis it was assumed that the search area corresponded with a distance of approximately 20 km. The dataset included live birds that died in care and excluded taxa considered to be essentially terrestrial (rails, passerines). The number of birds was lumped in periods of ten days (period 1 = day 1–9, period 2 = day 10–19, period 3 = day 20–31).

2.3. Total number of beached birds

The total number of birds that could theoretically be collected with each of the four approaches during one winter at the Belgian coast was calculated by extrapolating and adjusting the field data for the frequency and distance surveyed. First, missing values were estimated by inputting data according to consistent spatial differences in overall densities of corpses in three ways: (1) Incompletely covered sections in weekly, monthly or IBB surveys were extrapolated to the full distance of the section; (2) In 8 out of 168 sections (< 5%) that were not surveyed during specific monthly or IBB surveys, sec-

Table 1
Frequency and effort of various beached bird monitoring approaches applied at the Belgian coast during seven winters October–March 1993–1999

Winter	Weekly surveys		Monthly surveys							IBB surveys
	N	Interval (days ± S.E.)	Effort (% surveyed of 62.1 km coast)							Date
			October	November	December	January	February	March	Overall	
1993	22	8.2 ± 0.6	47	100	100	100	96	100	91 ± 9	Feb 13
1994	18	7.7 ± 0.6	0	100	96	96	100	95	81 ± 16	Feb 5
1995	14	12.1 ± 2.3	0	100	95	88	77	61	70 ± 15	Feb 18–24
1996	16	11.5 ± 1.7	75	84	84	100	100	95	90 ± 4	Feb 9–18
1997	19	8.3 ± 1.7	76	76	90	85	93	85	84 ± 3	Feb 21–27
1998	18	9.6 ± 1.5	74	78	91	93	82	82	83 ± 3	Feb 13–23
1999	17	9.3 ± 0.7	85	89	89	100	100	100	94 ± 3	Feb 11–15
Overall	124	9.3 ± 0.5	51 ± 14	90 ± 4	92 ± 2	95 ± 2	93 ± 4	88 ± 5	85 ± 3	

Interval = mean interval between successive ‘weekly’ surveys (days ± S.E.).

tion–correction factors were applied to obtain better estimates of the real number of beached birds. These factors (for the beach sections FRNP, NPOO, OOZB and ZBNL values of 1.43, 2.48, 0.79 and 1.86, respectively) were obtained by comparing the number of beached birds on these sections during 34 monthly surveys covering the entire Belgian coastline in the period January 1992–March 1999; (3) Two months during which there was no surveying effort at all (October 1993 and October 1994) were adjusted for by adding the mean value of all October months of the period 1993–1999.

In a next step these results were extrapolated to the full distance of the Belgian coast and to the entire winter period (October–March): (1) The results of 'weekly' surveys carried out on the section NPOO were multiplied by the section–correction factor 2.48 (see above) to obtain estimated total numbers for the entire Belgian coast; (2) Total numbers resulting from the 'IBB February surveys' were extrapolated to a full winter by applying a month–correction factor of 2.82. This factor was obtained in a similar way as described above for the section–correction factors and amounted to 15.08 (October), 10.61 (November), 8.68 (December), 4.31 (January), 2.82 (February) and 7.25 (March). This means that an analysis of 34 complete monthly surveys during 1992–1999 revealed consistent temporal patterns in stranding and that during e.g. December on average only 1/8.68 of the total number of bird corpses of an entire winter is found. In these recalculations temporal or spatial differences between species were not considered.

The final result is an estimate of the total number of beached birds per winter on the entire coastline, obtained for each of the approaches that has been used. By excluding the impact of travelled distance and variation in beaching intensity along sections, differences can be attributed entirely to variations in monitoring frequency.

2.4. Oil rates, number of species and occurrence of events

The oil rate is the fraction of complete bird corpses oiled of the total number found. For the purpose of this article two major taxa of beached birds were considered: auks (Guillemot *Uria aalge* and Razorbill *Alca torda*) and *Larus*-gulls. We assumed that, for both groups, a minimum of 10 specimens is required to calculate an oil rate. The small size of the sample of *Larus*-gulls in February did not allow including the International Beached Bird Survey in the comparison of approaches. Species richness was scored for each approach as the total number of species found, equivalent to Hill number N_0 (Hill, 1973). The sensitivity of each approach in detecting events of important bird stranding on the beach (wrecks, increased stranding due to oil-slicks and winter mortality of frost-sensitive species) is analysed by ranking the top-12 densities for Guillemot, Northern Fulmar *Fulmarus glacialis*, Kittiwake *Rissa tridactyla* or waders (as taxon) over the entire study period, grouping these high densities for each species into well-demarcated periods (events) and checking which of the four approaches was able to detect the event. Data from the MEC rehabilitation centre were grouped in 10-day periods and expressed as N km^{-1} (the majority of the birds of which their origin was documented appeared to originate from a 20 km beach section).

3. Results

3.1. Total number of beached birds

With 'weekly' surveys it is possible to collect on average 2687 corpses along the entire Belgian coastline each winter (Table 2). This is 6.6 times more than can be found during monthly surveys of the entire coast, a ratio corresponding quite well with the known minimal persistence time of corpses on Belgian beaches (5.8 days) during the same study period (unpublished data). At a single annual February (IBB) survey, the number of corpses that is collected is 3.0 times smaller than on six monthly surveys (135 vs. 406), a ratio well in line with the month–correction factor of 2.88 needed to extrapolate February results to a full winter. Hence, once the ratio in number of corpses between several winter months is well documented, results of an IBB survey can be used to estimate total number of beached birds in winter roughly. Annual mean total number of victims for monthly, IBB and weekly surveys divided by 6.6 are not significantly different from each other (Kruskal–Wallis test: $H_{(3,28)} = 3.47$; $N = 7$; $P < 0.05$).

Table 2
Estimate of total number of beached bird corpses and debilitated live birds that can be collected in winter at the Belgian coast, using different approaches

Winter/Method	W	M	I	I_x	MEC	RehC
1993	3301	256	68	192	123	382
1994	1655	216	66	188	171	531
1995	2067	307	56	158	139	432
1996	3921	644	234	661	132	410
1997	2338	465	90	254	134	416
1998	1935	297	49	140	132	410
1999	3592	654	381	1075	251	779
1993–1999: mean	2687	406	135	381	155	480
1993–1999: S.E.	340	69	48	134	17	53

Actual numbers of corpses collected each year in the field during weekly (W), monthly (M) or IBB (I) surveys are tabulated as well as the estimated number of corpses for an entire winter, based on a single February IBB survey multiplied by the correction factor 2.88 (I_x). As an estimate of the total number of live sea- and coastal birds that are collected annually by all Belgian coastal rehabilitation centres, data from the MEC rehabilitation centre were extrapolated (RehC).

Table 3
Oil rates (%) (and *N* birds scored) of beached auks (Alcidae) and *Larus*-gulls, as found in the period 1993–1999 at the Belgian coast using different approaches

Method	W		M		I		MEC	
Winter	Alcidae	Laridae	Alcidae	Laridae	Alcidae	Laridae	Alcidae	Laridae
1993	21 (152)	21 (44)	51 (84)	3 (36)	27 (18)	(3)	77 (60)	2 (45)
1994	56 (92)	4 (27)	70 (104)	9 (22)	52 (54)	(3)	88 (109)	0 (23)
1995	59 (24)	31 (32)	61 (75)	15 (40)	55 (20)	(4)	75 (83)	14 (22)
1996	31 (59)	6 (145)	46 (102)	3 (188)	53 (51)	2 (55)	74 (27)	2 (53)
1997	68 (43)	2 (32)	73 (83)	11 (104)	95 (43)	(9)	96 (50)	0 (34)
1998	53 (60)	19 (34)	52 (85)	11 (47)	57 (18)	(3)	84 (76)	0 (33)
1999	46 (161)	3 (38)	63 (300)	19 (47)	63 (207)	44 (10)	89 (180)	0 (21)
1993–1999: mean	48	12	59	10	57	24	83	3
1993–1999: S.E.	6	4	30	2	8		3	2

W = weekly surveys, M = monthly surveys, I = IBB surveys, MEC = rehabilitation centre.

According to the results of 'weekly surveys' from 1993 to 1999, an average yearly number of 2687 birds washed ashore (range: 1500–4000). This number has to be increased with 400–500 weakened, living birds collected through rehabilitation centres each winter (assuming an overall share of 40% by the MEC in the total number of Belgian coastal rehabilitated birds: Seys et al. (1999) or assuming the MEC rehabilitation centre targets about 20 km of the 62 km of Belgian beaches). Annual fluctuations become more important when frequency of surveying decreases: the proportion of maximal versus minimal yield amounts to 2.0 (MEC), 2.4 (weekly surveys), 3.0 (monthly surveys) and 7.7 (IBB surveys), respectively. The disproportionably high total number of birds estimated during the IBB survey in 1999 results from an important wreck of Guillemots and Northern Fulmar in February 1999 (Seys et al., 1999).

This rough estimate of total number of bird victims does not give the full picture of how many birds do really strand every year. Taking into account that during persistence experiments at the Belgian coast (unpublished data) 50–80% of the corpses have disappeared already within the first nine days (the mean interval between succeeding weekly surveys), many bird corpses must have been lost in between successive 'weekly' surveys. We estimate the real number of bird corpses beaching on the Belgian coast each winter might be as high as 5000–10,000 birds.

3.2. Oil rate

Oil rates of auks and *Larus*-gulls differ significantly when using another approach (Kruskal–Wallis test: $H_{(3,28)} = 13.76$; $N = 28$; $P < 0.01$ for auks; $H_{(2,21)} = 8.58; N = 21; P < 0.05$ for *Larus*-gulls). Post hoc comparisons demonstrate the MEC rehabilitation centre results differ significantly from all beached bird survey techniques ($P < 0.05$). Auks have much higher oil rates (on average 28% higher) at the MEC rehabilitation centre. *Larus*-gulls arriving at the rehabilitation centre are virtually free of oil, compared to mean oil rates of 15% in beached bird surveys (Table 3). There are no significant differences between the oil rates of Alcidae and *Larus*-gulls for the beach surveys at different frequency (though oil rates of Alcidae are about 10% lower in weekly, compared to monthly and IBB surveys).

When sections are added stepwise to the shortest section that was surveyed every month, oil rates in Guillemot stabilise from a travelled distance of 25–30 km onwards (40–50% of entire Belgian coast), which is equivalent to an average of 10–15 Guillemots found (Fig. 2).

Data from 118 'weekly surveys' in the period 1993–1999 with a minimal travelled distance of 10 km indicate that annual oil rates of Guillemot do not change substantially when the frequency of surveys is increased

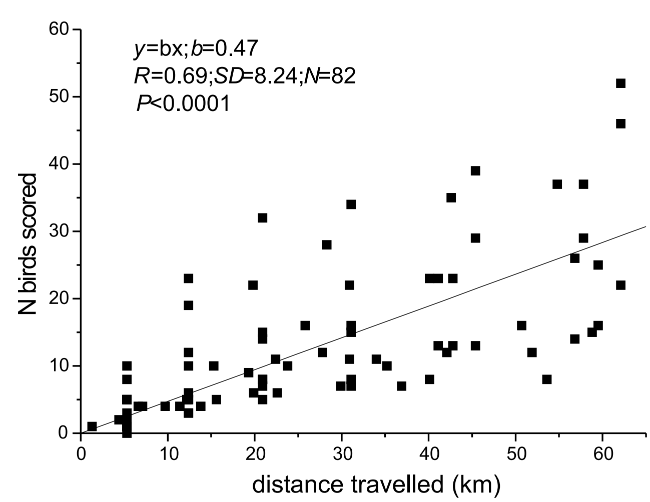

Fig. 2. The average number of complete Guillemot corpses collected during surveys at the Belgian coast (that can be scored on oil-contamination), in relation to the surveyed distance.

Table 4
Share of major taxonomic groups in the density of beached birds (mean % ±S.E.) and mean species richness (N_0 ± S.E.) in the winters of 1993–1999 at the Belgian coast using different approaches

Method	Grebes	Northern Fulmar	Gannet	Seaducks	Waders	*Larus*-gulls	Kittiwake	Auks	Species richness
W	2.9 ± 1.7	4.5 ± 1.8	1.5 ± 0.3	3.0 ± 0.6	9.7 ± 4.7	25.3 ± 3.7	5.7 ± 1.6	41.9 ± 5.8	27 ± 3
M	3.7 ± 0.9	5.9 ± 2.2	1.8 ± 0.3	3.4 ± 0.4	8.6 ± 3.8	24.0 ± 3.2	6.4 ± 1.5	40.3 ± 5.1	30 ± 3
I	3.6 ± 0.7	7.0 ± 3.3	0.4 ± 0.2	3.0 ± 0.6	8.6 ± 5.0	12.0 ± 2.8	5.6 ± 1.2	57.1 ± 7.0	15 ± 2
MEC	4.7 ± 1.0	1.1 ± 0.5	0.7 ± 0.2	2.4 ± 0.6	7.2 ± 2.3	26.7 ± 4.7	0.7 ± 0.4	53.9 ± 6.7	19 ± 1
Post-hoc comparisons			*I–W*			*I–W*	*MEC–W*		*I–W*
			I–M			*I–M*	*MEC–M*		*I–M*
			MEC–W			*I–MEC*	*MEC–I*		*MEC–W*
									MEC–M

W = weekly surveys, M = monthly surveys, I = IBB surveys, MEC = rehabilitation centre. Significant differences (Kruskal–Wallis: $P < 0.05$) are in italic, with significant post hoc comparisons indicated at the bottom of the table.

from 1 up to 3–5 times a month. However, a clear difference in oil rate in the various months of each winter, with high values (60–80%) in early winter and low oil rates from January onwards, strongly emphasise the need to spread beached bird surveying effort over the entire winter period. Since most Guillemots were collected in January–March, average oil rates in winter reflect the situation of this period.

3.3. Share of major taxa and species richness

The choice of a beached bird monitoring technique and the scale and frequency of the survey has an impact on the observed species composition. Weekly and monthly surveys show comparable results in terms of species richness and relative abundance of taxa (Table 4). The IBB survey, traditionally organised at the end of February, has a comparatively high share of auks (Kruskal–Wallis test: $H_{(3,28)} = 5.63$; $N = 28$; not significant at $P < 0.05$) and significantly lower numbers of *Larus*-gulls (Kruskal–Wallis test: $H_{(3,28)} = 9.05$; $N = 28$; $P < 0.05$) and Gannet (Kruskal–Wallis test: $H_{(3,28)} = 11.52$; $N = 28; P < 0.05$). This is consistent with the occurrence of auk wrecks mainly in late winter and gull and Gannet mortality particularly distinct in early winter. Live birds collected for the MEC-rehabilitation centre are more likely to belong to the Alcidae and typical offshore bird species (Gannet, Kittiwake) are underrepresented. Among the Laridae, the MEC rehabilitation centre receives relatively more Black-headed Gull, and less Herring/Lesser Black-backed and Great Black-backed Gulls (Table 5). This shift towards more 'land-oriented' gulls can be explained by the input of substantial numbers of gulls from inland polders. The number of species collected in winter (and over the entire study period 1993–1999) is significantly influenced by the distance travelled and the time-span covered (Kruskal–Wallis test between the four approaches: $H_{(3,28)} = 16.30$; $N = 28$; $P < 0.01$). As a consequence February surveys (IBBS) produce only half the number of species compared to 'weekly' and 'monthly surveys' (15 vs. 27–30; Table 4).

Table 5
Species-composition of beached *Larus*-gulls at the Belgian coast (1990s) and at the MEC rehabilitation centre (1988–1999)

Species	Proportion beach 1990s (%)	Proportion MEC 1988–1999 (%)
L. minutus	0.7	0.0
L. ridibundus	22.5	43.6
L. canus	11.2	10.3
L. argentatus/fuscus/cachinnans	57.5	39.7
L. marinus	8.1	6.5

Assuming that at the maximum travelled distance of 50–62 km during a monthly survey one obtains a reliable figure for the species-richness of the Belgian coast, a minimum distance of 40 km (or 65% of the entire coast) is needed to avoid deviations of more than 10% from this value (Fig. 3(a)). It is evident that the number of specimens that is collected – and not the surveyed distance in itself – determines the final value of the species-richness (Fig. 3(b)). It can be demonstrated that on average 50–100 birds should be collected to have a good sample of the species diversity found on the beach.

3.4. Occurrence of events

A detailed screening of the data shows 'weekly surveys' as the most sensitive procedure to detect events of mass occurrence of corpses on the beach (Table 6). In 84% of the important beaching events of Northern Fulmar, Guillemot, Kittiwake and waders, the event was revealed from weekly surveys. For monthly (63%), IBB surveys (32%) and the MEC rehabilitation centre (16%) sensitivity was (much) lower. Monthly surveys were as useful in some species (Northern Fulmar, Kittiwake, waders) but missed three out of four Guillemot wrecks observed in the period 1993–1999. Increased

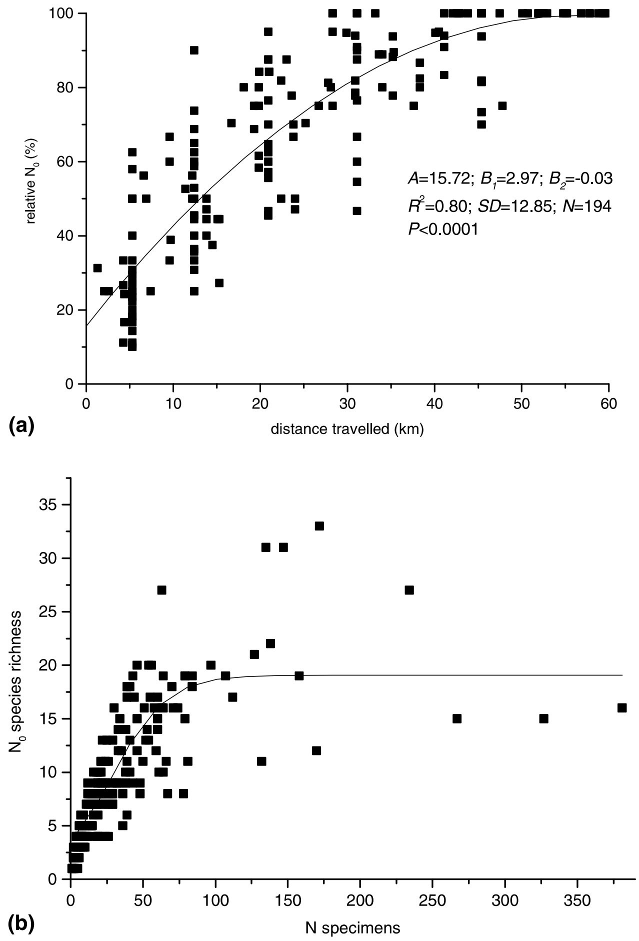

Fig. 3. Relationship between the collected number of beached birds, the distance surveyed and the species richness at monthly surveys, with (a) relative species-richness vs. distance surveyed; (b) species-richness vs. number of birds collected. Curves were fitted by eye.

mortality of waders due to cold winter spells in 1996 and 1997 was detected by most approaches. Small numbers of dead waders at the turn of the year 1992 were missed by all techniques except for the 'weekly surveys'.

The main reason why the MEC rehabilitation centre fails to detect the events in Table 6, is the small number of birds that is received compared to what is found during topical beach surveys. The temporal patterns in number of birds found dead on the beach and received alive at the rehabilitation centre are very much in line. All taxa that were regularly hosted at the rehabilitation centre (with at least forty birds during 1988–1999: grebes, scoters, waders, *Larus*-gulls, auks) show significant correlations with beached corpse numbers, both at a winter-to-winter and month-to-month level (unpublished data). Fig. 4 shows just one example of the similar seasonality of beached birds in the MEC rehabilitation centre, compared to beach data. The remarkable peak of Guillemot in December probably arises from a large number of tourists on the beach during Christmas holidays.

4. Discussion

The major objective of any beached bird monitoring scheme should be to obtain accurate data of the abundance of beached birds and the percentage of these birds that are oiled or contaminated with lipophilic compounds. Depending on whether one deals with an oil incident or with the effects of chronic pollution, either the assessment of total number of casualties or oil rates is emphasised. In addition beached bird monitoring may provide useful information on the occurrence of mortality events (mass stranding due to oil-pollution, food-shortage or severe winter weather, e.g. Clark, 1982; Underwood and Stowe, 1984; Piatt and Van Pelt, 1995; Piersma and Camphuysen, 2000) or indicate changes in relative abundance of bird species occupying the same habitat at sea. And it is undoubtedly a valuable source of background information on species characteristics (biometry, colour-phases, age, sex, e.g. Anker-Nilssen et al., 1988; Camphuysen and van Franeker, 1992; Stratford and Partridge, 1996), diet (through stomach analysis, e.g. Blake, 1983; Camphuysen and Keijl, 1994 or stable-isotope techniques, e.g. Hobson et al., 1994) and mortality factors other than oil, such as parasites (Brosens et al., 1996; Camphuysen, 2000), entanglement (Teixeira, 1986; Meissner, 1992; Camphuysen, 2001), plastic ingestion (van Franeker, 1985; Ryan, 1988), hunting (Raevel, 1990) or heavy metal contamination (Debacker et al., 2000).

4.1. Rehabilitation centres

The information on sea- and coastal-birds obtained through a coastal rehabilitation centre is different from that collected during beached bird surveys. The former might be a good source of information on debilitated or moribund, live coastal and inshore seabirds and function as a first alert. However rehabilitation centres do not provide reliable data on oil rates, a key factor in oil-monitoring programs. Oil rates in auks are significantly higher in the rehabilitation centre (83%) and lower in *Larus*-gulls (3%), probably due to a bias towards specimens that can easily be caught and be transferred alive to the centre. Oiled gulls are not easily taken alive, unless they have broken wings or legs. The latter are the main 'recorded' victims among gulls in rehabilitation centres at the Belgian coast. Lower oil rates in auks seemed to be linked to the probability of getting the bird in the rehabilitation centre in time (once it has died, as happens very often with exhausted 'wrecked' auks, the finder often decides not to bring the corpse to the centre). Similarly, Raevel (1992c) concludes that oil rates are systematically higher in the centres of Northern France compared to those determined on the beach (e.g. Razorbill: 99% vs. 65%; Guillemot: 98% vs. 73%).

Table 6
Sensitivity of different beached bird monitoring approaches (I = IBB surveys, M = monthly surveys, W = weekly surveys, MEC = rehabilitation centre) in detecting events with high densities of corpses of Northern Fulmar, Kittiwake, Guillemot or waders on Belgian beaches during the study period 1993–1999

Event				Sensitivity of method (%)				
Species	Events (period)	N (km^{-1})	Oil rate (N)	Detected by	W	M	I	MEC
F. glacialis					67	83	33	0
	21/1/95	0.40		M				
	18–20/10/97	0.24–0.41	23 (13)	W M I				
	21–25/1/98	0.24		W M				
	23/2/98	0.30		M I				
	30/3/98	0.30		W				
	15/2–3/3/99	0.24–1.67	29 (115)	W M I MEC				
R. tridactyla					83	67	17	0
	27/1/93	0.84		W				
	28/2/93	0.36		W				
	21/1/95	0.39		W M				
	25/11/95	0.24		M				
	19/12/97–25/1/98	0.24–0.48	50 (28)	W M				
	15/2/99	0.44–0.48	69 (29)	W M I				
U. aalge					100	25	25	25
	27/1–12/3/93	1.86–2.81	15 (124)	W				
	1–11/2/94	1.44	39 (61)	W				
	9–15/1/95	1.89–3.58		W				
	15/2–14/3/99	1.40–3.67	51-92 (367)	W M I MEC				
Waders					100	67	33	33
	6/1/93	1.20	0 (20)	W				
	1/2–24/3/96	1.40–2.38	1 (159)	W M I				
	5–30/1/97	0.48–2.98	0 (158)	W M MEC				
Summary for all 19 events					84	63	32	16

The sensitivity of each approach is tested by ranking the top-12 densities for each species (group) over the entire study period, grouping these high densities for each species into events (periods) and scoring how many of these events could be tracked by each approach. The sensitivity of each 'method' is expressed as the proportion of the events that was signalled by the approach.

The number of live birds that is received at Belgian coastal rehabilitation centres every winter is estimated at 400–500 specimens and is thus small compared to the numbers of corpses found on the beach (on average 2700). Raevel (1992c) mentions even smaller relative numbers of live birds collected through rehabilitation centres in N-France, amounting to 90–400 'centre' birds in winter, compared to 370–3500 beached corpses at IBB surveys only. As to prevent an underestimation of numbers and oil rates, Raevel suggests including live birds from rehabilitation centre. We suggest to keep the data from rehabilitation centres separate from data on beached corpses, since the former are much more effort-dependent than beach surveys (and thus related to weather conditions, occurrence of events, etc.) and can usually not rely on the same degree of data quality as for BBS. Although oil rates in the most common taxa differ for both approaches, general temporal patterns in relative densities and oil rates at the beach and in rehabilitation centres are comparable. It does not come as a surprise that the species richness recorded at the MEC rehabilitation centre and during IBB surveys is significantly smaller than during weekly or monthly surveys. In addition the species composition is also markedly different. Late February IBB surveys have a comparatively high share of auks (most auk wrecks in second half winter) and low numbers of *Larus*-gulls (mortality

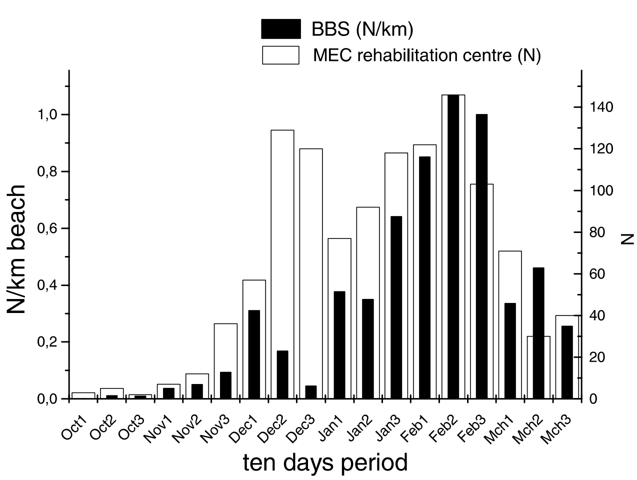

Fig. 4. Comparison of the temporal pattern in the number of Guillemots received at the MEC rehabilitation centre and those found dead on the beach.

in this group concentrated in early winter). Offshore species such as Gannet and Kittiwake are underrepresented at rehabilitation centres (Table 4).

4.2. Comparison of beached bird survey approaches

In order to obtain reliable data from beached bird surveys in the most efficient way, one should ensure a high enough surveying frequency, a spacing over the entire winter period and a large enough distance as to make sure a sufficient number of corpses can be collected (Camphuysen and Heubeck, 2001).

The advantages of increasing the frequency of surveying from once a month to 'weekly' are comparatively small. The four beach monitoring approaches we applied all led to reliable estimates of total number of beached birds. Data from IBB surveys can be translated into very rough total winter estimates provided the average contribution in numbers of beached birds by month is known, and both monthly and IBB surveys will approach the total estimates shown at weekly surveys when multiplied by a persistence correction factor.

Oil rates of auks are slightly, but not significantly reduced at weekly surveys (48%) compared to monthly (59%) or IBB surveys (57%), a difference resulting neither from the higher frequency of the surveys, nor from the spatial variation in beaching along the Belgian: oil rates are reduced from 57% to 55% when considering only the section at monthly surveys coinciding with the weekly surveyed stretch of beach (Oostende–Nieuwpoort). Probably the slightly reduced oil rates in auks in 'weekly surveys' are caused by the higher probability to include wreck-events into the figures as the frequency of monitoring is increased. The two winters with values in 'weekly surveys' deviating most distinctly from results of 'monthly' and 'IBB surveys' are those with typical wreck conditions (1993 and 1999). Three out of four peak-densities in Guillemots during the seven winters of study were not detected by monthly surveys. All of those peak values were due to massive stranding or 'wrecks', i.e. events with low oil rates. It appears the major advantages of increasing the frequency from monthly to 'weekly' be the higher probability to detect events or the additional number of corpses that can be collected for further analysis (or for drift or other experiments).

More important than a very high frequency is a large enough spacing of the surveys throughout the winter (and when possible, throughout the year). A homogenous distribution of surveys over an entire winter season (October–March) is essential due to marked differences in oil rate throughout the year. Wrecks with high numbers of unoiled beached seabirds were frequent at the Belgian coast during the period 1993–1999 and typically occurred in the second half of the winter. Guillemots showed peak densities ($> 2.5\ \mathrm{km}^{-1}$) in February 1993, January 1995 and February–March 1999, Northern Fulmars knew only one important mass stranding i.e. in February–March 1999. If one decides to carry out only one beached bird survey a winter, it is essential to organise it in the same month each year, which in fact is the basic idea behind the IBB surveys. Spatial variation in beaching intensity even on a small scale (such as the Belgian coast: unpublished data) urges to space surveying effort over the entire length of the coastline. To be statistically representative, survey beaches need to be randomly distributed. This is in accordance with Camphuysen and Heubeck (2001), who propose a selection of subregions covering the entire coastline, and in response to local conditions.

4.3. Impact distance

The number of species collected in winter is largely influenced by the distance travelled (function of the number of specimens that can be collected) and the timespan covered. Single surveys such as the IBB survey produce only half of the species richness observed at weekly or monthly surveys. That species composition for weekly surveys is similar to monthly surveys is also mentioned by Bodkin and Jameson (1991). For the Belgian coast (62.1 km of sand beaches) a reliable species richness deviating not more than 10% of the maximal species spectrum at every monthly survey is obtained at ca. 40 km coverage ($= 65\%$). This corresponds with a total number of 50–100 birds collected. Both weekly and monthly surveys meet these requirements when data are cumulated up to winter scale. Raevel (1992b) obtained similar results. Although he indicates that species richness has not reached its upper limit at the maximal distance of 173 km under study, some 65% of this distance (i.e. 112 km) will already produce about 85% of the species richness.

We found a minimum of 25–30 km (40–50% coverage) is needed to attain stable oil rates in the Guillemot. Raevel (1992b) mentions 25–30% coverage (i.e. about 50 km out of a 173 km shoreline) as a minimum, but according to figures presented in his paper a survey on only 10% of the study area (i.e. 17 km) will give oil rates with deviations of only 10%. This corresponds with the 10% minimum suggested by Camphuysen (1991b) to obtain reliable figures for various subsections at the Dutch coast. However it is not distance in sea, but a sufficiently large sample that will lead to stable oil rates (see also Camphuysen and Heubeck, 2001). As a consequence, in every other study-area the distance that should minimally be travelled will vary with the density of beached target species and therefore depend on season, occurrence of events etc. In addition it is recommendable to focus on easily accessible beaches, where a substantial proportion of the beached corpses will actually be found. In terms of cost-efficiency it is not advisable to spend much time on rocky, slippery coast

Table 7
Evaluation of various beached bird monitoring approaches applied at the Belgian coast during the winters 1993–1999

Approach	Weekly surveys	Monthly surveys	IBB surveys	MEC rehabilitation centre
Oil rate	++	++	+	–
Total number	++	++	+	[a]
Events	++	+	–	+[b]
Species richness	++	++	–	–
Consistent data since	1992	1986	1962	1984
Taxonomic groups	++	++	–	–
Yield of corpses 1993-99	1916	2673	910	1082
Time investment field work per winter (man days)	18	24	4	–[c]
Relative financial input	4.6	6	1	–

Score: ++ = good results; + = fairly good results; − = unreliable results. The total field time investment per winter at the Belgian coast amounts to 36 man days (survey methods partly overlapping, see Section 2). A rough estimate of the financial input for each BBS-method does not take into account the data analysis phase and assumes all field work is done by professionals.
[a] Needed as additional information.
[b] Good as to signal most but not all events, effort-dependent and hence biased.
[c] No manpower needed to comb the beaches, but personell essential to run the rehabilitation centre.

sections where many corpses might be hidden in crevices and remain undetected for the surveyor.

At the Belgian coast, the proposed 25–30 km corresponds with an average 'yield' of 10–15 Guillemots. Assuming one needs at least 10 specimens to get reliable annual oil rate figures for the Belgian coast for a species/taxon, only Guillemot provides sufficient corpses each winter in weekly, monthly as well as IBB surveys. *Larus*-gulls meet this criterion only in weekly and monthly surveys, Razorbill only with 'weekly' effort. For the much longer Dutch coast, Camphuysen (1995) selects seven taxa/species that are sufficiently common and widespread to be used as 'key-species' for oil-monitoring: Guillemot, Razorbill, Kittiwake, Northern Fulmar and Gannet (offshore species), Common Scoter *Melanitta nigra* and Velvet Scoter *M. fusca* (inshore species) and *Larus*-gulls (both). The need to cover 25–30 km (oil rates) up to 40 km (species richness) of beach at the Belgian coast in order to obtain reliable oil-monitoring data put a further intensification of mechanical beach cleaning activities during winter into question.

5. Conclusions

Essentially time investment and hence the cost of the various approaches is dependent on the travelled distance and on the frequency of the surveys. Assuming that professionals carry out all surveys, monthly surveys are slightly more expensive and time-consuming than weekly surveys (Table 7). However, since a well-trained network of volunteers largely carries out monthly surveys in Belgium and the Netherlands, monthly surveys turn out here to be the most cost-effective ways to get accurate information on beached birds.

The set-up of a beached bird surveying programme depends on the objectives one has in mind. To meet the minimal requirements in terms of oil-pollution data collection, a single IBB survey on the most accessible 10% (long coastlines) to 50% (short ones cf. Belgium) of the targeted coastline satisfy, preferably synchronic with other neighbouring countries. IBB surveys, restricted to a single action in February, give fairly good data on density and oil rates of beaching birds. On the other hand they cannot give more than a picture at a given moment and hence fail to signal events. And in small study areas such as the Belgian coast, very few species provide enough specimens for oil rate calculation. Its main value is the international character of the scheme and its long history (and hence important databases). For at least the Belgian and Dutch situation (Camphuysen and Heubeck, 2001) a survey in February coincides with the period of maximal beaching. If the objective is to quantify the number of debilitated or moribund, live birds that come ashore and to point out problems at sea in a more or less continuous ways, data from rehabilitation centres should be added. However these data cannot be used directly to indicate oiling in seabirds due to an important bias of the data. Moreover numbers of birds collected are proportionally small, collection takes place in a non-standardised way and important stranding with no or only few living victims might be missed completely. Most satisfactory results (lowest effort versus best results, with a good coverage of the entire coast) are obtained by monthly surveys on a large enough part of the shoreline. They give reliable data on oil rates and total numbers, represent all species and taxa and are reasonably sensitive in detecting events such as wrecks, small oil slicks, winter mortality, etc. Increasing the effort to 'weekly' surveys, will enhance the sensitivity in detecting short-lasting events and provide additional bird corpses for necropsy examinations, etc. The former can also be achieved by combining monthly surveys with data collection through at least one well-runned rehabilitation centre. When the centre signals important stranding events, additional beached bird sampling can then be organised. As a general conclusion, a beached bird monitoring programme should minimally include participation in the International Beached Bird Survey at the end of February on a beach section that provides enough bird corpses for oil rate calculation in some key taxa/species. It is most desirable to extend the February survey to monthly monitoring, at least during winter months. More frequent surveying does not add much new information.

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