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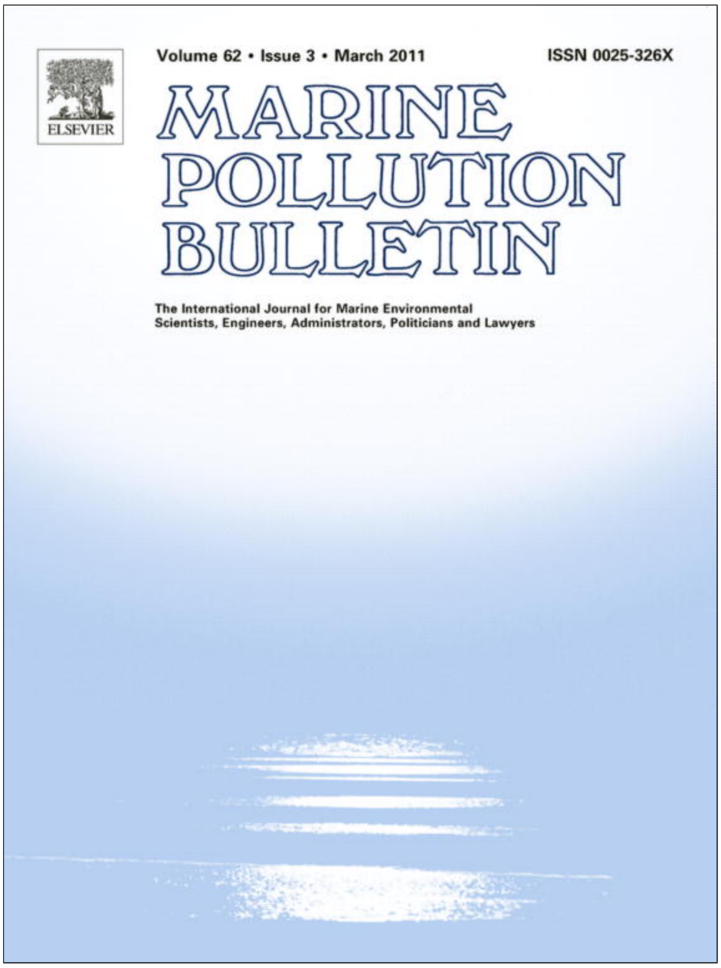

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Seabirds and chronic oil pollution: Self-cleaning properties of gulls, Laridae, as revealed from colour-ring sightings

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ABSTRACT

Mystery oil spills off the Dutch coast affected colonial, adult Lesser Black-backed Gulls prior to and within the breeding season. From colour-ringed individuals, it was demonstrated that most oiled birds survived and were clean within a few weeks and often bred successfully. Further evidence of self-cleaning properties of *Larus*-gulls is provided from a long-term colour-ringing project (1984–2009). In total 46 birds were reported 'oiled', two died, but the majority cleaned itself and survived for up to 20 years after being oiled. From colour-ring data and 30 years of beached bird surveys (1980–2010) it is demonstrated that the effects of chronic oil pollution is larger in winter than in summer; a reflection of seasonal differences in exposure and environmental conditions. The self-cleaning properties of gulls are such that long-term survival is not necessarily jeopardised and even in a breeding season, not all is lost in case of a spill.
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1. Introduction

Seabirds, worldwide, suffer from the effects of relatively small, illegal oil spills at sea (chronic pollution; Camphuysen, 2007). Seabirds are particularly sensitive, because mineral oil ruins the insulating properties of their plumage, which they require to survive in a maritime environment. Even a small amount of oil on individual birds can be lethal. Oil transferred from incubating gulls to their eggs results in high levels of embryo mortality compared with controls (King and Lefever, 1979). However, while the literature on the adverse effects of oil on the plumage of seabirds is extensive (Portier and Raffy, 1934; Koth and Vauk Hentzelt, 1988; Jenssen and Ekker, 1990, 1991; Rozemeijer et al., 1992), there is at best anecdotal evidence of oiled birds in the wild that were capable of cleaning themselves (Birkhead et al., 1973; Dixon and Dixon, 1976), let alone on their long-term survival and breeding success. It is clear, however, that at least some birds survive without human interference (Phillips, 1974; Tangen, 1984; Dierschke, 1994; Reijnders, 1997).

The self-cleaning properties of colonial, colour-ringed Lesser Black-backed Gulls *Larus fuscus* were studied following a series of mystery oil spills in summer 2009 and spring 2010 off the Dutch coast. A spill in April 2010 affected hundreds of adult breeding birds in colonies on the islands Texel and Vlieland (W Wadden Sea area), still actively engaged in pre-laying prospecting behaviour and the re-establishment of partnerships. The other spills affected breeding birds during incubation and chick care. The survival of these oiled birds and their hatchlings was such that an analysis was undertaken of a much larger set of data, that had accumulated in the course of a 25 year colour-ringing programme (1986–2010). This paper reports on the demonstrated, often long-term survival (without human interference) of oil-contaminated colour-ringed Lesser Black-backed Gulls and Herring Gulls *Larus argentatus*, from re-sightings later in life between 1986 and 2010. Finally, specific results of 30 years of beached bird surveys in The Netherlands (1980–2009) are analysed to evaluate the current seasonality in risks and effects of chronic oil pollution on Laridae, an important group of coastal seabirds.

2. Methods

Three datasets were explored for the analysis. The effects of oil on colonial Lesser Black-backed Gulls at Texel (Wadden Sea islands, The Netherlands, 53°01′N latitude, 04°43′E longitude) were determined from observations in the 2009 and 2010 breeding seasons. Within the study area, approximately 11,500 pairs of Lesser Black-backed Gulls and just over 5000 pairs of Herring Gulls are nesting (van Dijk et al., 2010). Frequent colony visits were used to monitor the effect of the oil on colour-ringed individuals (and their offspring) and revealed their self-cleaning potential. Camphuysen and Gronert (2010) provided photographic documentation of the self-cleaning success of one particular case: a largely oiled, incubating adult Lesser Black-backed Gull in May 2010 that managed to fledge one chick.

A second set of data involved 3997 Herring Gulls colour-ringed as chicks in 14 Dutch colonies between 1986 and 1988 (*c.* 100 per

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colony per season; Camphuysen, 2008) of which 86,703 sightings were logged within The Netherlands and abroad between 1986 and 2010 (Camphuysen et al.). In earlier and subsequent more ad hoc campaigns, a further 686 Herring Gulls, 1172 Lesser Black-backed Gulls, 13 Yellow-legged Gulls *Larus michahellis*, and 12 hybrids between any of these species were colour-ringed in Dutch colonies (ringing effort 1984–2009) and the 26,988 reported sightings were checked for evidence of plumage contamination by mineral oil and subsequent survival. The reporting protocol for sightings did not include a request to report the physical condition of the observed individual, so that any reports of peculiarities resulted from the common sense of the observer. Reported incidences of oiling must therefore represent at best a minimum estimate of the number of contaminated individuals over the years.

Thirdly, results of beached bird surveys in The Netherlands between 1980 and 2010 were analysed to evaluate trends in oil-rates (the percentage of oiled birds of the total number of birds found). This percentage of oiled stranded birds (y) presumably has some s-shaped relation with some index of oil pollution (x). A mathematical representation of such an s-shaped curve is the logit function:

$$Y = e^x/1 + e^x \quad (1)$$

This analysis focuses on this index of oil pollution, the *oil-rate*, which equals

$$X = log(Y/1 - Y) \quad (2)$$

Trends in oil-rates were therefore calculated after logit-transformation of the data by means of linear regression by least-squares estimation (Camphuysen and Van der Meer, 1996; Camphuysen, 2010). The statistics accompanying these calculations include n, a, b, se_b, r^2, r.m.s., t and the level of significance. Trends were considered significant if $P < 0.05$. The underlying dataset comprised 10,092 counts covering 61,348 km of shoreline (25% in summer, May–October, 75% in winter, November–April), during with 44,032 gulls, Laridae, were found dead.

Furthermore, the amount of oil on dead stranded individual gulls was examined. Only intact carcasses could be used for this exercise. Of all beached dead gulls reported, 4549 carcasses were both oiled and 'complete' and thus suitable for the inspection of the amount of oil on the feathers. In 2047 (45%) of these, an estimate of the amount of oil on the plumage was indeed provided. The amount of oil on affected birds was scored by adding 10% for each wing surface area (upper and lower, left and right, total 40%), 30% for the entire underside of the body being oiled, 30% for the entire upper surface, leading to 100% in specimens totally covered in oil. Single specks of oil anywhere in the plumage were normally scored as 1%, so that any value between 1% and 100% oiling for individual contaminated birds could occur. Scores were rounded, however, for reasons of simplicity, to the nearest value including.

Specks of oil: 1% of plumage oil-fouled (Fig. 1a),
Slightly contaminated: 5% and 10% of plumage oiled (Fig 1b),
Partially oiled: 25% or 50% oiled (Fig 1c),
Largely oiled: 50–75% oiled (Fig 1d), and.
Completely oiled: 75–100% oiled.

The same categorisations were used for birds observed alive. Seasonal patterns and other trends in the amounts of oil on dead oiled gulls washing ashore were examined.

3. Results

With regard to the self-cleaning and reproductive activities of oiled Lesser Black-backed Gulls during breeding, three events were documented: (1) a single, partially oiled individual during chick care in July 2009, (2) hundreds of oiled gulls in at least two breeding colonies in the prospecting phase in April 2010, and (3) a few rather heavily oiled individuals, one of which monitored, during incubation, hatching and chick care, May–July 2010.

The first case comprised an adult male Lesser Black-backed Gull, ringed M.ADM, reported as partially oiled (30%) on 8th July 2009 in the final phase of chick care. The pair had two fledglings under care when the male became oiled, but both chicks fledged successfully in August. When exactly this bird cleaned its plumage is unknown (no further sightings within season), but the bird returned fit and healthy in the 2010 season from its wintering grounds and reoccupied the territory successfully. It is also unclear whether the (oiled) male bird had contributed to this breeding success, but given that the 2009 season was a particularly poor breeding season as a result of food shortages offshore, it is unlikely that a single (non-oiled) parent bird could have fledged two chicks.

The second case involved 8.3% of all adult birds present during the prospecting phase in April at the southern tip of Texel. This colony numbered 10,500 pairs in 2009 (Stork, 2010), and because the spill occurred when 32.2% of the colour-ringed individuals in that area had returned in the early phase of prospecting, an estimated 560 adults may have become oiled. Observations in neighbouring colonies indicated that the oil had affected birds in colonies all over the island Texel and on the neighbouring island Vlieland, but apparently at a slightly lower level (<5%). The fact that no Herring Gulls were oiled, but only Lesser Black-backed Gulls, points at an offshore rather than nearshore oil spill. Beached bird surveys in April 2010 on Texel, Vlieland, and in the neighbouring part of the mainland coast did not produce a single stranded oiled gull. The amount of oil on individual birds visiting the colony ranged from

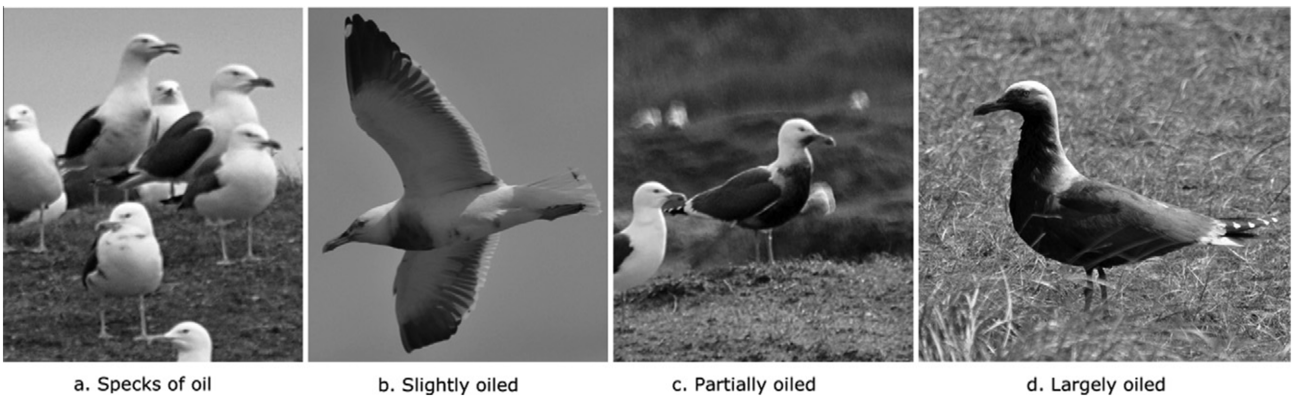

Fig. 1. Examples of categories used relative to the amount of oil recorded on individual Lesser Black-backed Gulls (photos CJ Camphuysen).

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Table 1
Amount of oil visible (coverage, %) on colour-ringed colonial Lesser Black-backed Gulls, breeding phase, apparent breeding success, and days spent self-cleaning until the plumage was apparently free of oil; Texel colonies, 2009–2010.

Colour ring	Oiling date	Coverage (%)	Breeding phase	Breeding success	Self-cleaning
M.ADM	8 Jul 2009	30	Chick care/fledging	2 chicks fledged	(alive in 2010)
M.AAC	3 April 2010	45	Pre-laying	Not breeding	26 days
M.AKS	3 April 2010	5	Pre-laying	Breeding	15 days
F.ACW	3 April 2010	5	Pre-laying	Not breeding	13 days
F.ACS	3 April 2010	25	Pre-laying	Not breeding	20 days
M.AMZ	24 May 2010	65	Incubation	1 chick fledged	>30 days

a few specks to partial or near-complete oiling. Even partially and largely oiled birds behaved 'normally' (territorial and courtship behaviour), but most partially and largely oiled individuals disappeared from the colony for at least several days following the event. Several of the oiled birds had been colour-ringed in previous breeding seasons and all these recovered within 2–4 weeks (Table 1). Their plumage was clean during visual inspections, even at very close range. Three birds were territorial with established pair bonds at the end of the month; still prior to egg-laying. For reasons unknown, many adult Lesser Black-backed Gulls (including numerous colour-ringed birds that had not been oiled) gave up their breeding attempts and left the colony. Three of the previously oiled colour-ringed birds were among those, while one continued to breed successfully.

The third case involved a small spill affecting a dozen or two adult Lesser Black-backed Gulls incubating eggs on 24th May 2010. One largely oiled, unmarked individual (65% of body oiled) occupied a territory within the main study plots. This bird was colour-ringed (code M.AMZ) to monitor its possible recovery. It is unknown whether fuel oil or crude oil was involved. Self-cleaning took time, but was successful within a period of 30 days (nearly completely clean; some specks of oil in the wing and neck remaining; Camphuysen and Gronert, 2010 for details). Meanwhile, the affected bird successfully shared the incubation of a 3-egg clutch and produced fish boluses during handling (indicating foraging activities at sea). The eggs hatched and at least one chick fledged successfully with a growth rate that was not different from the overall colony mean.

3.1. Further evidence for self-cleaning in colour-ringed Laridae

Out of 4944 individually colour-marked *Larus*-gulls ever seen alive since ringing between 1984 and 2009, 46 individuals (0.9%) have been reported as being oiled at least once in their life-time (6 Lesser Black-backed Gulls, 0.6%, n = 1012; 40 Herring Gulls, 1.0%, n = 3906). Of these, 26 were reported in winter (Nov–Apr), 20 in summer (May–Oct). A relatively large number (20) were observed in 1990 and in fact 80% of all reports originated from a six-year period (1988–1993), immediately following the main ringing campaign (1986–1988, 4123 gulls marked; Fig. 2). Most birds were ringed as chicks and as a result, a rather large proportion of the oiled birds were immatures (58.7% 3rd–5th calendar year). Reports of oiled, colour-ringed Lesser Black-backed Gulls were received from France (1×) and The Netherlands (5×), oiled colour-ringed Herring Gulls were reported from Belgium (5×), France (4×), Germany (1×), and The Netherlands.

Colour-ringed birds reported as 'oiled' may have been detected only well after the actual contamination took place. Hence, reported amounts of oil on the feathers are essentially minimum amounts (birds may have been actively cleaning their feathers for a while). Four Lesser Black-backed Gulls were slightly oiled, two were partially oiled (>25% of the plumage). All six birds were seen clean later in life, with a mean post-contamination survival of 797.3 ± 224.0 days (Table 2). A total of 40 Herring Gulls have been reported as oiled, including two juvenile birds that were reported as dead. The mean post-contamination survival of the other 38 individuals averaged 2321.5 ± 303.2 days (Table 2), with no significant difference between individuals that were recorded as partially oiled or only slightly oiled ($t_{32} = 0.03$, $P = 0.488$). One adult bird has never been reported since the record of a speck of oil on the cheek of the bird, one immature with some oil on the head was reported clean 3 days later, but has never been recorded since (apparent survival 3d), while another immature with some oil on the cheek was reported apparently clean 12 days later, but never since. These were the only individuals that may not have survived, although the amount of oil recorded was unlikely to have caused

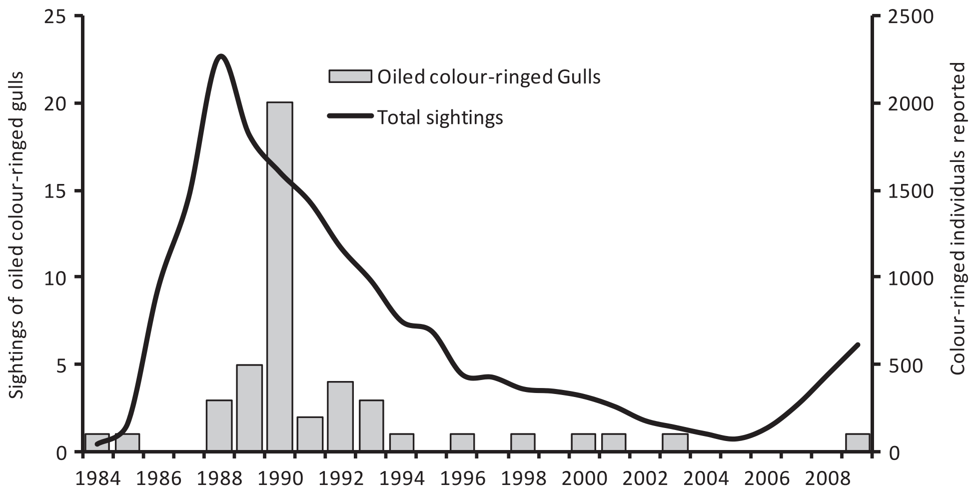

Fig. 2. Annual frequency of oiled *Larus*-gulls (bar graph) relative to the total number of individually marked gulls reported in each year, known to be alive (line graph).

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Table 2
Apparent minimum survival (d) of 44 oiled colour-ringed gulls since the last observation of an contaminated plumage (mean, SE, sample size, minimum and maximum survival).

Species	Oiling	Mean ± SE	*n*	min	max
Lesser Black-backed Gull	Slightly-Partial	797.3 ± 224.0	6	65	1432
Herring Gull	Slightly	2331.4 ± 372.6	25	0	6801
	Partial	2307.3 ± 751.0	9	182	7492
	Unknown	2291.5 ± 669.1	4	822	3977
	All	2321.5 ± 303.2	38	0	7492

death. All other Herring Gulls were observed at least 3 months later, with a maximum of 20.5 years since the oiling occurred. Repeated sightings of oiled colour-ringed individuals revealed that even partly contaminated individuals were apparently clean within a period of only two weeks. The observed post-contamination survival of birds reported oiled in winter (1518 ± 255 d) was significantly lower than that of birds observed in summer (2974 ± 505 d; $t_{42} = -2.81$, $P < 0.01$).

3.2. The risk for gulls to become contaminated with oil: beached bird survey results 1980–2010

Of 26,149 intact carcasses of *Larus*-gulls found along the shoreline in The Netherlands during systematic beached bird surveys between 1980 and 2009, 17.6% were contaminated by oil. The species composition of winter strandings was highly consistent over the years with 0.7 ± 0.4% (mean ± SD) Little Gulls *Hydrocoloeus minutes*, 15.6 ± 2.9% Black-headed Gulls *Chroicocephalus ridibundus*, 18.6 ± 5.1% Common Gulls *Larus canus*, 2.5 ± 0.9% Lesser Black-backed Gulls, 51.9 ± 6.4% Herring Gulls, and 10.8 ± 3.6% Great Black-backed Gulls *Larus marinus*. A similar consistency was found in summer 1980–2009: 0.2 ± 0.2% Little Gulls, 21.2 ± 10.8% Black-headed Gulls, 3.3 ± 2.2% Common Gulls, 9.5 ± 4.5% Lesser Black-backed Gulls, 61.4 ± 11.8% Herring Gulls, and 4.5 ± 2.4% Great Black-backed Gulls. The oil-rate was considerably higher in winter (29.4%, $n = 13{,}768$) than in summer (4.4%, $n = 12{,}381$), and the oil-rate in both periods declined significantly over the past 30 years (winter r.m.s 0.09, se $b = 0.01$, $t_{30} = -10.73$, $P < 0.001$, summer r.m.s. 0.10, se $b = 0.01$, $t_{30} = -9.86$, $P < 0.001$; Fig. 3). While 50% of the gulls found in winter in the early 1980s were contaminated with oil, this declined to only one in fifty carcasses (2%) in recent years and current oil rates in summer are negligible (Table 3). Calculating a seasonal pattern over the entire period (1980–2009), oil-rates declined markedly in spring (March–May), dropped to very

Table 3
Oil rate (mean ± SD, % of birds found oiled of all intact carcasses found) of *Larus*-gulls in winter and summer in five-year periods since 1980 in The Netherlands.

Five-year period	Winter (November–April)	Summer (May–October)
1980–1984	52.3 ± 8.6	18.3 ± 16.1
1985–1989	26.2 ± 3.3	7.0 ± 3.7
1990–1994	19.0 ± 3.5	2.7 ± 1.1
1995–1999	10.5 ± 4.1	1.9 ± 0.7
2000–2004	8.6 ± 6.2	0.6 ± 0.3
2005–2009	2.4 ± 3.1	0.6 ± 0.6

low levels in late summer (August–September), increased in late autumn (November–December) and peaked in winter (January–February; Fig. 4). Of the more completely documented carcasses, in winter, 41.6% were only slightly oiled, 27.0% were partially oiled, and 31.4% were near-completely oiled ($n = 1795$). In summer, the corresponding percentages were 63.1%, 25.0, and 11.9% respectively ($n = 252$; Fig. 4). There was a positive correlation between the monthly oil rate and the fraction of near-completely oiled carcasses found on the coast ($R_S = 0.85$, $n = 12$, $P < 0.01$).

4. Discussion

While declines in oil-rates of stranded birds have clearly demonstrated the reduction of chronic oil pollution over the past decades, the problem is still apparent (Camphuysen, 2010). Seabirds that spend most of their time afloat (swimming), certainly those that cannot survive onshore for any length of time (e.g. auks, divers or loons, grebes), are the most sensitive to oiling. Even small amounts of oil in their plumage cause such birds to give up diving, which means they cannot any longer feed, and most such casualties are due to starvation. For more aerial species, in particular for taxa that can safely roost ashore, the effects should be less

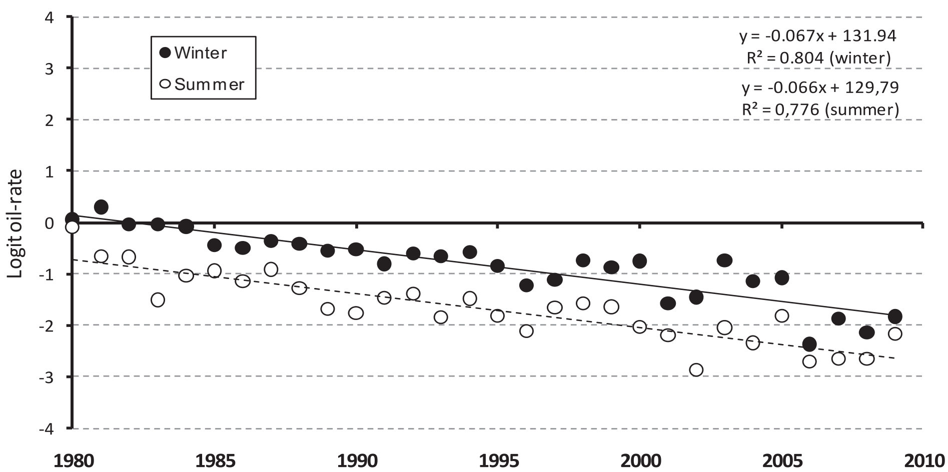

Fig. 3. Logit-transformed oil-rates (% of birds found oiled of all intact carcasses found) for *Larus*-gulls found in The Netherlands in winter (November–April), and in summer (May–October), 1980–2009.

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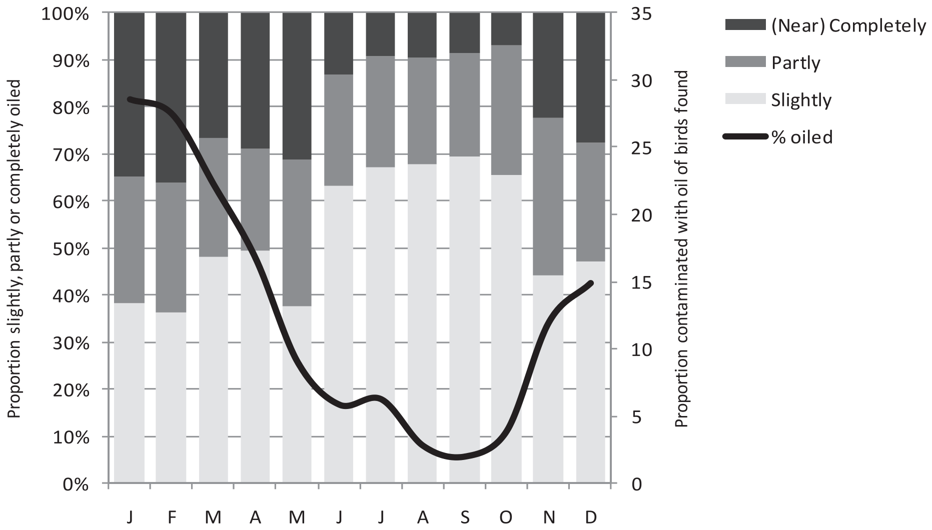

Fig. 4. Monthly oil rate (% of birds found oiled of all intact carcasses found, line) of *Larus*-gulls found dead along the Dutch coast, 1980–2009 (n = 26,149 intact corpses), and the relative abundance (%) of slightly (1–24% of plumage contaminated), partly (25–74% contaminated) or (near-) completely (⩾75% contaminated) corpses (stacked bar graph; based on n = 2047 carcasses).

dramatic (King and Sanger, 1979; Camphuysen, 1989). Gulls are one group of seabirds that are not fully restricted to marine prey resources, and that when in distress, could seek refuge on land. Yet, worldwide beached bird surveys have demonstrated that Laridae are common casualties during oil spills.

The first 2010 oil spill affected a large number of Lesser Black-backed Gulls preparing to breed on Texel and Vlieland (Natura 2000 areas that are under special protection as nature reserves). The loss of many hundreds of prospecting adults, early in the nesting season, would have been a serious blow to the breeding population. Aerial surveillances of the area did not result in positive observations of oil at sea at the time, so incident was logged as a mystery spill (Dutch coastguard pers. comm., 5 April 2010). Thanks to the fact that a well-studied part of the colonies was affected, it was possible to study the effect of the spill. None of the nesting Herring Gulls were oiled, only Lesser Black-backed Gulls, which indicated that the spill must have occurred relatively far offshore rather than a nearshore. Strandings of fresh, oiled Northern Fulmars *Fulmarus glacialis* and Northern Gannets *Morus bassanus* confirmed this suggestion (Dutch Seabird Group, BBS unpublished data, April 2010). How many heavily oiled gulls were lost at sea during the spill will remain unknown, but none have washed ashore.

The assumption that in particular the more heavily oiled individuals would simply disappear and die was violated by the results of our observations. All colour-ringed individuals, two of which largely oiled in early April, managed to clean their plumage within a few weeks; in time to establish breeding territories and commence breeding. While nearly 10% of all observed gulls were at least slightly oiled in early April, it was hard to imagine that anything had happened at all after only 2 weeks: no oiled birds visible anywhere. There are no reasons to believe that the other, unmarked oiled birds within the colony, at least generally, suffered a different fate. There were no finds of (oiled) dead birds anywhere within or around the colony and certain characteristic, territorial individuals that were known to have been oiled in early April re-appeared in the course of that month. The results indicate that full-grown gulls may overcome even rather substantial oiling of their plumage with few adverse effects.

4.1. Colour-ring database

Well over 40 examples from the extensive dataset on colour-ringed Herring Gulls and Lesser Black-backed Gulls monitored since 1984 gave further evidence for the self-cleaning properties of Laridae. None of the colour-ringed birds had been treated in specialised rehabilitation centres (treatment and ringing details would have been reported to the colour-ring database manager). It was usually impossible to follow individual birds with frequent sightings to measure the speed of recovery, but existing evidence suggests that even partly contaminated gulls managed to clean themselves within weeks. Once clean, their survival seemed uncompromised, given the number of years that many of them have lived ever since.

Birkhead et al. (1973) suggested that the ability of wild birds to clean oil from their plumage depends upon the amount, type and toxicity of the oil and on its distribution over the plumage. Birds must restore the feather micro-structure and water repellence and survive the toxic effects of oil ingested during this process (Bourne, 1969; Butler and Lukasiewicz, 1979; Briggs et al., 1997). Gulls are noted for their ability to digest unnatural food items and probably have relatively resistant digestive systems. This may account for their ability to successfully remove oil from their plumage (Clark and Kennedy, 1971). The time of year and weather conditions are probably important, since oiled birds are under greater stress during low ambient temperatures and adverse weather. The significantly lower post-contamination survival for colour-ringed birds oiled in winter than for birds oiled in summer could be seen as a confirmation of this point. Still, the majority of the birds observed in either season survived for a considerable number of years after the oiling occurred.

4.2. Beached bird surveys

The vulnerability to oiling of *Larus*-gulls is usually considered moderate to low; much lower for example than genuine 'seagulls' such as Black-legged Kittiwakes *Rissa tridactyla* (King and Sanger, 1979; Williams et al., 1995; Camphuysen, 1998). Their tendency to roost on land rather than on water, their aerial foraging

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techniques, their take-off rather than diving response in case of oil slicks and the high reproductive rates of current breeding populations are all factors that reduce the Oil Vulnerability Index calculated for this group of seabirds. Winter beached bird surveys in the 1980s in The Netherlands, however, demonstrated that despite a lower anticipated risk to become oiled, still rather large numbers died as a result of chronic oil pollution. Over time, oil rates have declined, particularly so in coastal seabirds (Camphuysen, 2010). However, the beached bird surveys have highlighted also that not all slightly oiled individuals manage to clean their feathers. The risk to die from oil is apparently much larger in winter than it is in summer. Apart from ambient temperature and bad weather, some more factors are important to explain this difference. Species like Herring Gulls and also Mew Gulls *Larus canus* have a much greater tendency to forage at sea in winter than in summer, also at considerable distances from the shore. This tendency to feed far out at sea in winter is probably a need rather than just an option. The much higher oil-rate in the winter season is thus a reflection of the resulting difference in exposure to oiling. Oil-rates were lowest directly after the breeding season, which is in fact a period of post-nuptial (complete) moult for several species. Herring Gulls are uncommon at sea in August and much of September (Stone et al., 1995) while they finalise the moult of their flight-feathers. This must have contributed to the dip in oil rates found during beached bird surveys in that period.

Oil rates alone, or rather the quantities of oil on individual birds, may be difficult to evaluate if the type of oil involved is left out of consideration. From visual inspections, however, even the most basic distinction of oil types into crudes and fuels oils is impossible, let alone different levels of toxicity. Some heavy oils immobilise individual birds immediately, and it is likely that such oil types are difficult to remove for birds without human interference. Lighter oils, but also warmer seasons and less cold waters, may enhance the possibilities for self-cleaning in individual seabirds. The results from the colour-ring programme and the observations in the breeding colony at Texel, however, clearly demonstrate that even rather heavily oiled individuals (partially and largely oiled), against all odds, cannot only just survive and clean their feathers, but sometimes even continue breeding and raise chicks successfully.

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