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Short communication

Oiling of live gulls as a tool to monitor acute oil spill effects on seabirds

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Oiling of seabirds is a serious ecological threat to marine ecosystems worldwide (Wells 2001). Because they spend much of their lives at sea, seabirds are particularly prone to marine oil pollution exposure, with short- and long-term population consequences (Peterson *et al*. 2003). In seabirds, the degree of exposure to oil is dependent upon ecological and behavioural traits related to habitat use that may differ among species, populations, age classes and sexes (Day *et al*. 1997, Votier *et al*. 2005, Martínez-Abraín *et al*. 2006). Due to their high vulnerability and exposure, seabirds have been used as bio-indicators of marine oil pollution for many decades (Furness & Monaghan 1987, Burger & Gochfeld 2004). The most important monitoring method draws from beached bird survey schemes, as they are thought to provide important evidence to assess geographical and temporal patterns in chronic oil pollution at sea (e.g. Seys *et al*. 2002, OSPAR Commission 2005).

Here we present a novel non-intrusive approach that can be useful to assess oil effects on seabirds based on the monitoring of oiling rates in live free-ranging gulls. The few attempts to date of systematically recording oiling rates in live marine birds have been used to evaluate temporal changes in the exposure of Common Terns *Sterna hirundo* and Black Skimmers *Rhynchops niger* to chronic oil pollution (Duffy 1977, Gochfeld 1979, Erwing *et al*. 1986). To assess the feasibility of this method, we established a monitoring scheme to record oiling rates in live gulls in a coastal area affected by the *Prestige* oil spill disaster in Galicia (northwest Spain). The spill started in November 2002 and, as a result, thousands of marine birds, mostly wintering auks (Alcidae) from Great Britain and Ireland, died in the following months, and other seabird populations were negatively affected (Velando *et al.* 2005, Votier *et al.* 2005). We found that the temporal pattern of visible oiling in live gulls was coupled with the temporal occurrence of dead and impaired oiled seabirds at beaches.

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METHODS

The oil spill

On 13 November 2002, the oil tanker *Prestige*, loaded with 77 000 tons of heavy fuel, sent an SOS alert off Cape Fisterra, Galicia (southeast North Atlantic). At least three massive oil pollution pulses consisting of over 60 000 tonnes of oil hit the coasts of Galicia. The first reached the coast 3 days later, the second (main) spill occurred at the moment the ship broke up and hit the coast on 1 December 2002 and the last spill washed ashore around 3 January 2003. As an indication of the amount of oil at sea during our study period we used data provided by the Technical Office of Marine Spills (OTVM) relative to oil recovered by ships (http://otvm.uvigo.es/cartografia/residuosRecogidos.html). Clean-up operations at sea succeeded in removing 18 997 tons of oil between 25 November 2002 (day 12) and 23 February 2003 (day 102).

Gull survey and monitoring

Gulls with oil-stained plumage were visually monitored with the aid of binoculars and 20–60× telescopes in the coast of Galicia south of O Grove, Pontevedra. The outer stretches and islands of this 281-km coastline were hit by the second and third *Prestige* oil spills. Observations started 6 days after the first spill began and were made on a daily basis until day 38 and then every second or third day until the end of February. Thus the study period comprised the first 100 days of the spill. The survey was entirely land-based and mostly undertaken from accessible places where gulls were known to roost or feed regularly (sandy beaches and fishing harbours). Data consisted of 48 401 direct observations of gulls, of which 26 222 were obtained by the same two observers and the rest by volunteers. The sample was largely dominated by adult Yellow-legged Gulls *Larus michahellis* (n = 35 549), followed by *Larus michahellis/Larus fuscus* immatures (n = 9647), Black-headed Gulls *Larus ridibundus* (n = 5603), adult Lesser Black-backed Gulls *Larus fuscus* (n = 1579) and Great Black-backed Gulls *Larus marinus* (n = 74). It is likely that the majority of observations of immature gulls corresponded to Yellow-legged Gull juveniles and first-years, as the ratio between Yellow-legged and Lesser Black-backed Gulls was close to 20 : 1 in birds in adult plumage. The average flock size was 52.8, sd = 63.2 birds (median = 32.0) for 808 flocks.

To estimate how common oiling was within the observed gull population, we measured oiling (i.e. the presence of obvious oil stains in the plumage of individuals) in terms of its daily prevalence in the sampled population. Prevalence (oiling rate) was taken as the proportion of oiled gulls relative to the total number of gulls observed (Gochfeld 1979).

Beached bird survey data

During the period of our study, a total of 9330 aquatic birds (seabirds, waterbirds and waders) were recovered from beaches in Galicia through a beached bird survey scheme in which hundreds of volunteers intensively searched the oiled littoral zone for several months (data provided by Dirección Xeral de Conservación da Natureza, Xunta de Galicia). This represented 77.6% of the total number retrieved by 31 August 2003 when the survey was concluded. Most of the birds reported (81.7%) were alcids, and 8.2% were gulls, mostly Yellow-legged Gulls.

Statistical analysis

Our measure of synchrony was the cross-correlation function (CCF), a measure of the strength of the association between two temporal variables that provides information on typical time lags between events. It was computed between paired observations of oiling prevalence in live gulls and the number of oiled seabirds reported by beached bird surveys, with the aid of the SPSS Statistics17.0 software. Prevalence for the days with no gull counts was interpolated using a linear function. Our data were subject to high serial correlation because daily counts were not independent. There were no missing values in the beach survey data. Similarly, cross-correlation analyses were performed between data on the amount of oil removed at sea by clean-up ships and, respectively, observations of oiling prevalence in gulls and beached bird data.

RESULTS

Oiled gulls were detected as soon as the monitoring scheme was set up. Our results suggest substantial differences among species in both the degree and the pattern of oiling exhibited in the aftermath of the *Prestige* oil spill (Fig. 1). The cross-correlation analyses revealed that oiling in Yellow-legged Gull adults and large immature gulls acted as a leading indicator of beached bird survey data at positive delays of 1–8 days, although cross-correlograms peaked at delays of 4–6 days (Fig. 1). In contrast, the temporal pattern of oiling in both Black-headed Gulls and adult Lesser Black-backed Gulls failed to show a significant correlation with beach survey data (Fig. 1).

The strongest and only significant correlation between oil removed at sea by clean-up ships and oiling prevalence in gulls was achieved on day 0 (i.e. no delay) in immatures ($r = 0.486$, $P < 0.05$), adult Yellow-legged Gulls ($r = 0.398$, $P < 0.05$) and adult Lesser Black-backed Gulls ($r = 0.395$, $P < 0.05$). Neither oiling in Black-headed Gulls nor beached seabird casualties were correlated with the amount of oil removed at sea by ships ($P > 0.05$ in all time lags).

DISCUSSION

The monitoring of gulls in a coastal area hit by a large oil spill has revealed that several days before seabird casualties were washed ashore, there was an increase in the number of adult Yellow-legged Gulls and immatures showing oil stains in their plumages. The strongest temporal synchrony between such events was obtained with positive lags of 4–6 days. Therefore, the results indicate that oiling in gull populations forecasted subsequent events of oiled seabird mortality on beaches caused by a large oil spill.

The majority of seabird casualties in Galicia were wintering alcids. Therefore, the link between oiling prevalence in gulls and seabird mortality is based upon cross-correlations with the temporal pattern of alcid mortality. Yellow-legged and Lesser Black-backed Gulls are widespread and common over the entire relatively narrow (25–30 km) coastal shelf of Galicia (Valeiras 2003), where they broadly overlap with wintering alcids. We have no data on how or where the gulls became oiled, although correlations with the amount of oil recovered at sea by clean-up ships suggest that it is likely that many became oiled at sea. Moreover, differences in the prevalence of oiling between gull species are in agreement with differences in exposure related to spatial distribution and marine habitat use (e.g. Kubetzki & Garthe 2003). Therefore, the highest levels of oiling were found in the more pelagic Lesser Black-backed Gull, whereas oiling prevalence in the Black-headed Gull, a species generally restricted to the coast, was considerably lower (Fig. 1). The high synchrony with beached bird data exhibited by Yellow-legged Gulls contrasted with the lack of association found in Lesser Black-backed Gulls. It should be noted that in Galicia, Yellow-legged Gulls are strictly sedentary (Munilla 1997), whereas the great majority of the Lesser Black-backed Gulls surveyed were wintering transient birds and so possibly less attached to the study area. Because winter gull populations in the study area are not closed, temporal changes in oiling prevalence are influenced by the movements of gulls (whether clean or oiled) to and from the study area. On the other hand, oiled birds may

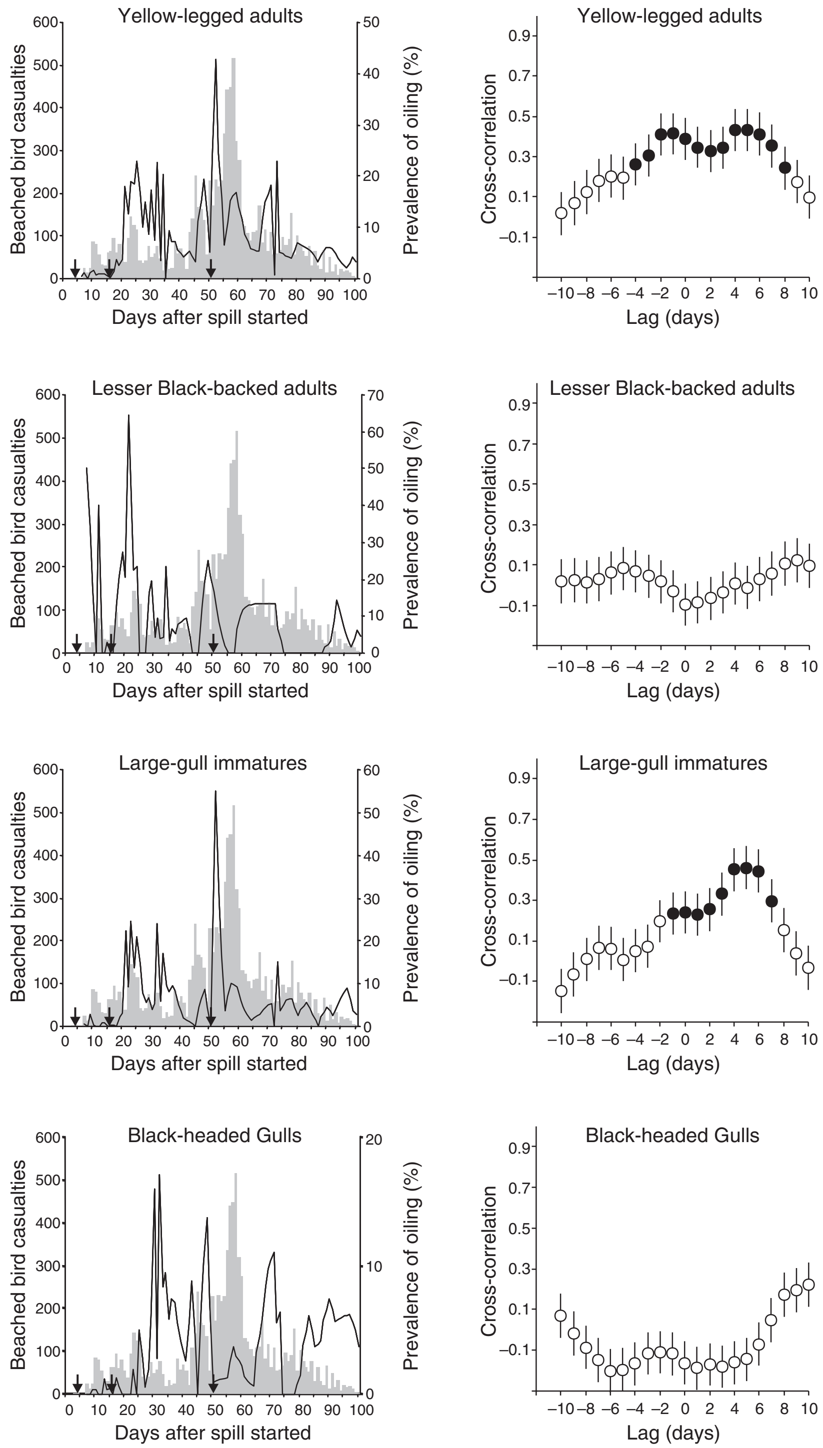

Figure 1. Daily changes in the number of beached birds retrieved from the coast of Galicia (bar diagram) and the prevalence of oiling in gulls (line diagram) during the first 100 days following the *Prestige* oil spill. Arrows on the *x*-axis indicate the time when the three main spill pulses first reached the coast. The dot graphs on the right show the degree of synchrony between the two time series within a time-lag interval of ± 10 days as indicated by cross-correlation analyses. The number of beached birds was taken as the model for oiling in gulls, so positive lags mean that oiling in gull populations anticipates beached bird numbers. Black dots indicate statistically significant cross-correlation values.

succeed in removing oil stains by preening, thus changing their oiling status or, if they suffer from acute oil intoxication, they may die or become disabled and go undetected.

Diving seabirds, especially alcids, are known to suffer oil spill related mortality in disproportionate numbers to their representation in the coastal seabird community (Piatt *et al.* 1991). The specific causes for this sensitivity are unclear, although the alcid species most at risk of oiling remain at sea during winter and roost on the water surface. In contrast, gulls are surface-feeding seabirds that commonly roost on land. Therefore, gulls that eventually became oiled (but not severely impaired) in offshore waters can be detected as soon as they return to land, whereas in the case of alcids it usually takes several days after oiling until they are washed ashore (Wiese 2003, OSPAR Commission 2005). This may explain the existence of a time lag between oiling in gulls and the beaching of seabirds, as apparently happened in the aftermath of the *Prestige* disaster.

Besides being a technique with little disturbance to birds, a monitoring scheme based on the survey of white-plumaged, large-sized gulls has a number of advantages and could be easily integrated into oil pollution monitoring programmes that rely on beach bird surveying (Seys *et al.* 2002). Indeed, in middle and high latitudes of the northern hemisphere, including many areas with intense oil bunker traffic, closely related species of the Herring Gull complex (Liebers *et al.* 2004) are widely distributed and widespread within at least 100 km offshore (Kubetzki & Garthe 2003). Moreover, these gull species gather in relatively large flocks at predictable places and are easily approached; thus, oiled individuals are unlikely to go unnoticed and large sample sizes over broad coastal areas can be efficiently collected at relatively little cost and effort. For example, our study area (a 281-km coastline) could be surveyed by just two observers working separately in just one day.

It is uncertain whether the synchrony patterns suggested by our results apply to other oil incidents or if they were just a consequence of the prevailing conditions and particular circumstances of the *Prestige* oil spill. The processes governing the beaching of seabirds may vary considerably over time within and between areas, as shown by drift-block experiments that try to mimic the drift of oiled seabirds and seabird carcasses. These experiments indicate that the recovery rates of alcid-like blocks released at sea are highly dependent on wind direction and are extremely low in offshore wind conditions (Flint & Fowler 1998 and references therein). While further evidence on its validity is needed, our results suggest a simple way in which gulls can be useful to generate information about the presence of oil lethal to seabirds in the marine environment. Therefore, in addition to beached bird surveys, live gull surveys may be a very useful additional source of information that contributes to a more accurate picture in assessing occurrences and impacts of oil incidents on the marine avifauna.

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