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Estimation of the impact of prevailing weather conditions on the occurrence of oil-contaminated dead birds on the German North Sea coast

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Estimation of the wind impact on oil-contaminated bird corpse observations

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Abstract

Chronic oil pollution by illegal oil dumping in the North Sea is difficult to quantify. Beached, oil contaminated sea birds, however, may be used as an indirect indicator. Reconstructing the drift of oil slicks and sea bird corpses in the southern North Sea for the period 1992 – 2003 by means of a two-dimensional numerical transport model driven by re-analysed weather data, we show on example of two common sea bird species that the variability observed within the number of corpses registered during beached bird surveys for the German coast primarily reflects the inter-annual variability of prevailing weather conditions. This should be taken into account when interpreting the data. We propose normalisation of beached bird survey data based on numerical drift simulations to improve the recognition of trends in the level of chronic oil pollution.

Introduction

While oil spills resulting from ship accidents attract much public interest, less dramatic, ongoing sources of oil pollution receive less attention. However, major oil pollution of the marine environment is caused by accidental discharges that occur during normal shipping operations or by illegal oil dumping, such as tank washing or the disposal of bilge water[1,2]. Shipping routes in the North Sea are among the busiest worldwide and the vast traffic in this area causes damage to the marine biota[3,4,5]. The amount of oil spilled into the sea, however, is difficult to estimate, as chronic oil pollution often goes undetected[6]. To get an approximation of trends in the magnitude of chronic oil pollution, continuous surveys of oil contaminated sea birds, typical victims of oil pollution, are conducted. However, the number of beached birds is also influenced by other factors including, for instance, wind conditions[7,8,9]. This complicates the interpretation of beached bird surveys.

For the period 1992 – 2003 we show using the results for two common sea bird species (Guillemot (*Uria aalge*) and Common Scoter (*Melanitta nigra*)) that neglecting the impact of changing weather conditions could for some species lead to a misinterpretation of the results of beached bird surveys carried out on the German coast. We propose an approach for normalisation, which efficiently reduces the meteorological signal and allows for a better assessment of possible trends in the number of corpses found during the surveys and hence in the general level of chronic oil pollution.

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Beached bird surveys

Beached, oil contaminated sea birds have been used as an indicator of chronic oil pollution since the 1960's[7]. With the increasing recognition of the problem of oil pollution in the marine environment, the monitoring area has been enlarged and the beached bird surveys have been improved. On the German North Sea coast, surveys have been performed by volunteers twice a month during the winter season (October to March) since 1984. The results of beached bird surveys are used as an indirect measurement of chronic oil pollution. Analyses of oil samples indicate that the majority of birds are contaminated by heavy fuel oil from shipping[8].

Figure 1.a illustrates the annual number of oil contaminated Guillemot (*Uria*

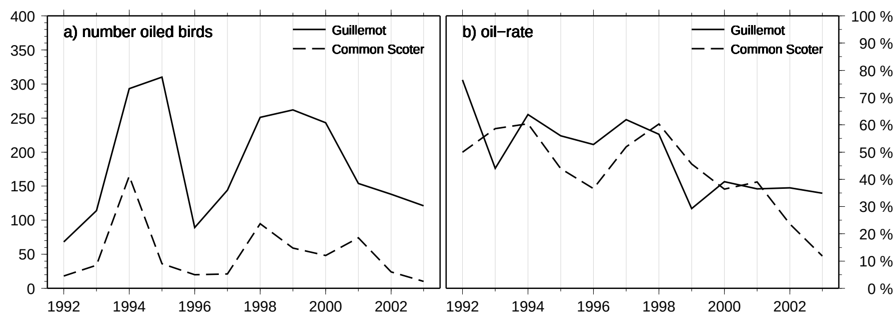

Figure 1: (a) Number of beached, oiled Guillemot (solid line) and Common Scoter (dashed) at Germany's North Sea coast and (b) the percentage of beached Guillemot (solid) and Common Scoter (dashed) that were oiled within the period 1992 – 2003 (Jan.–Mar.,Oct.–Dec.).

aalge, solid line) and Common Scoter (*Melanitta nigra*, dashed) beached on the German North Sea coast in 1992 – 2003. These are relatively numerous bird species that are vulnerable to oil pollution[8,10,11]. Guillemots are sea birds, which are in winter distributed predominantly offshore in and around busy shipping routes (Stefan Garthe, personal communication). For this reason this species is preferred for the indication of chronic oil pollution[7]. Common Scoters live at or near the coast.

Of note is the huge variability in the data presented in figure 1. In addition to oil pollution several other factors affect the number of birds recorded. For example, the number of oiled birds depends on the distribution and the size of their population[12]. To normalise results, the percentage of beached sea birds that were oiled, the so-called oil-rate, is used as an indicator[8] (figure 1.b). However, circumstances such as mass mortality as a result of either extremely low temperatures, avian diseases or nutrition deficiencies also influence the oil-rate[7,8,9]. In addition, wind conditions regulate the number of beached sea birds and in some circumstances the oil-rate. To our knowledge, the quantification of the impact of weather conditions on beached bird data has not been studied systematically.

Numerical simulation of wind drift effects

Although aware that wind influenced the number of corpses recorded on the German North Sea coast, there was no attempt to standardise its affect in the past[11]. In our study we exploit model based high resolution information about past atmospheric winds and North Sea currents (*www.coastdat.de*) to improve the quantitative handling of wind effects on beached bird survey data. Based on Lagrangian drift simulations we attempt to produce a detailed picture of weather related annual variability within the beached bird survey data.

Given oil pollution at a certain location, it is impossible to say exactly when and where contaminated birds will die. Therefore, as wind drift factors happen to be similar for oil slicks and bird corpses[13,14], tracer particles are considered to be representative for drift behaviour of both items. As the majority of chronic

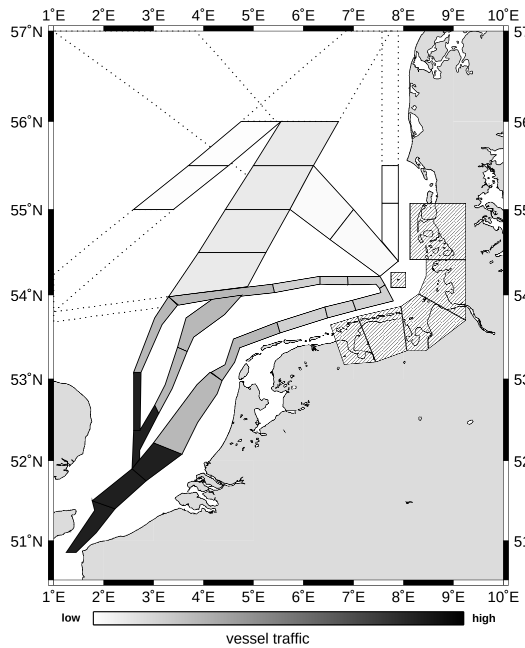

Figure 2: Particle source regions containing all major shipping routes (different levels of grey shading represent different densities of shipping traffic[15,16]) and target regions along the German coast (hatched).

oil pollution in the southern North Sea originates from ships[8], source regions for tracer particles are defined that contain the major shipping routes in the North Sea[15,16] (figure 2). Simulations are initialised in 28h intervals. For each source region the number of simulated tracer particles reaching the German coast is re-weighted according to a) the estimated density of ship traffic and b) particle travel time, assuming exponential decay with a decay constant of 21 days.

In figure 3 the weighted numbers of stranded tracer particles are compared with the survey data already pictured in figure 1. Simulations are restricted to the winter months when the surveys are conducted. Inter-annual variability of model results and beached bird statistics in 1992 – 2003 correspond surprisingly well. The numbers of oil contaminated Guillemots and Common Scoters recorded at the tideline seem to correlate with the intensity of weather driven transports towards the coast. The oil-rate of Common Scoters shows a similar pattern. An apparent moderate long term decline in the number of both oiled Guillemots and Common Scoters (cf. figure 1) appears to be mirrored by a trend in the advective transport. This is also recognisable in the oil-rate of the latter species. On the contrary, fluctuations in the oil-rate of Guillemots do not follow the same pattern as the weighted numbers of stranded tracer particles. Guillemots occur throughout the southern North Sea area[10] in the vicinity of the busy shipping routes and are the first species to be hit by oil slicks. Common Scoters

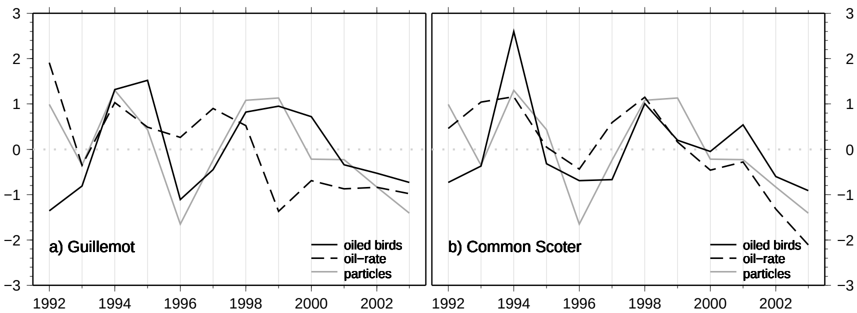

Figure 3: Black lines: Survey data re-displayed in standardised form from figure 1.a (number of beached, oiled birds; solid) and figure 1.b (oil-rate; dashed) representing a) Guillemot and b) Common Scoter. Grey line: standardised annual number of simulated tracer particles (selected months: Jan.–Mar., Oct.–Dec.) that reach the German North Sea coast (cf. figure 2) if exponential decay with a decay constant of 21 days is assumed.

on the other hand live close to the German North Sea coast. The more oil that reaches the German coastal area from the shipping lanes, the more likely it is going to contaminate Common Scoters and other coastal species. Hence, the number of surveyed, oil contaminated Guillemot corpses is not expected to correspond to the oil-rate. The oil-rate of Common Scoters is, however, expected to be positively correlated to the number of beached, oiled individuals of this species.

Looking at model simulations that cover a longer period of 46 years (1958

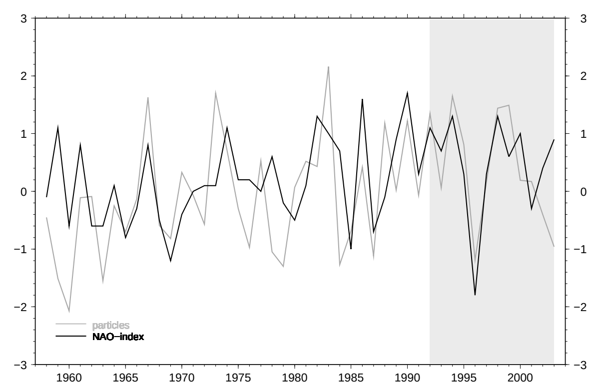

Figure 4: Black line: mean NAO index. Grey line: annual numbers of simulated tracer particles that reach the German coast assuming exponential decay with a decay constant of 21 days. All data refer to the selected months (Jan.–Mar.,Oct.–Dec.) and have been standardised. Grey shaded: period of the investigated beached bird surveys.

– 2003) suggests the existence of trend-like variations on the scale of decades (figure 4). In particular, an increasing trend in attained simulated tracer particles precedes the declining trend after 1994 that is suggested by figure 1 and 3. According to figure 4 changing strengths of particle advection towards the German coast are in close correspondence with variations of the North Atlantic Oscillation (NAO) index representing sea-level pressure differences between the Icelandic low and the Azores high[17]. High index values are accompanied with

strong westerly winds so that more tracer particles reach Germany's coastal regions. Particle advection is less effective for low NAO index values.
As changing wind conditions affect the drift of both oil slicks and contaminated birds, the close correspondence between variations and trends in the survey data and weather driven model results, respectively, does not come as a surprise. Our study shows that wind conditions may affect the results of beached bird surveys especially the numbers of corpses recorded and in some situations even the oil rate. When relating the results of beached bird surveys of coastal species to changing levels of chronic oil pollution it is important to take this into consideration.

Data normalisation

To improve the interpretation of the beached bird survey data in terms of trends in the level of pollution, we propose statistical normalisation based on the assumption of a linear relationship between simulated passive tracer transports and observations of beached birds[18]. We use the following linear regression model

$$y_i = a + bx_i + \epsilon_i$$

where x_i is the percentage of simulated tracer particles that reach the German coastline in the year i (winter season) and y_i is the corresponding value of either the number of contaminated birds or the oil-rate of the corresponding bird species. Residuals ϵ with zero mean represent inter-annual variations that cannot be (linearly) attributed to variable meteorological conditions. Normalised survey data $\hat{y}_i$ may then be obtained from

$$\hat{y}_i = \bar{y} + \epsilon_i = y_i - b(x_i - \bar{x})$$

where $\bar{x}$ and $\bar{y}$ denote average values for the period and sea bird species under consideration.
Results of subjecting the standardised survey data from figure 3 to normalisa-

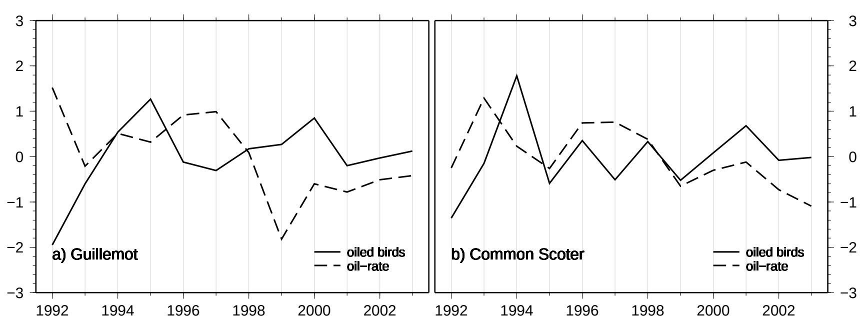

Figure 5: Standardised numbers of beached, oiled sea birds (solid) and oil-rates (dashed) after the application of data normalisation for a) Guillemot and b) Common Scoter.

tion are shown in figure 5. Lowering (raising) values in years with strong (weak) onshore drift conditions, produces a more uniform time series. The number of oiled Common Scoters in 1994, however, remain on high level in both the original data and the normalised numbers as mass oiling was recorded in that year[8]. In October 1998 large numbers of mainly coastal sea birds fell victim to oil that was spilled after the cargo vessel PALLAS grounded on the German North Sea coast[19]. The 1998 peak in figure 3.b (Common Scoter) becomes inconspicuous

after data normalisation. Hence, if wind conditions had happened to be different, less coastal sea birds, such as Common Scoter, might have contaminated by oil.
It should be kept in mind that even if normalisation with regard to wind conditions worked perfectly, the time series of beached birds would still remain influenced by other factors[7,8,9], especially mortality and distribution.

Conclusions

We conclude from ensemble Lagrangian passive tracer transport simulations that inter-annual variability of wind driven advection towards the German coast is large and has a high impact on the number of oil contaminated, beached Guillemots and Common Scoters beached there. The corresponding oil-rate, however, reacts differently depending on the distribution of the birds involved. The oil-rate of the Common Scoter, a coastal species, for instance, seems to be influenced by wind. In particular, a pronounced negative trend in advective transport during the last decade might lead one to believe that the oil-rate for that species has declined steeply on the German North Sea coast, reflecting a much reduced level of oil pollution in adjacent waters. Using normalised values the decline is in fact not so steep. Model simulations for the period 1958 – 2003 put the negative trend in wind driven transports since about 1994 into the context of a long-term variability that is connected with variations of the NAO index. Normalisation of survey data on oil contaminated birds assuming a linear relationship with simulated passive tracer advection is proposed to improve interpretation and to avoid misinterpretation of beached bird survey data.

Methods summary

The Lagrangian trajectories of passive tracers were calculated based on state-of-the-art reanalyses of past atmospheric and sea state conditions in the North Sea. Detailed hindcasts of shelf sea currents with hourly resolution were taken from the data base coastDat (*www.coastdat.org*). They are the result from running a two-dimensional finite element model (TELEMAC-2D[20]) on a triangular grid with a variable spatial resolution between a couple of kilometres offshore and about 100 meters near the coast[21]. Regional atmospheric fields stored in coastDat and employed to force the marine model at its upper boundary were produced based on NCEP re-analyses[22], using the regional climate model SN-REMO[23] for dynamic downscaling. Vertical displacements of tracer particles were simulated stochastically. For particles at the water surface, an additional drift of 1.8% of the 10m wind was superimposed[13,14]. This additional drift component was assumed to decrease with water depth if particles submerge. To properly resolve the history of weather related drift processes in 1958 – 2003 in the German Bight, drift simulations for ensembles of 2700 particles each were initialized every 28 hours in the vicinity of the major shipping routes. Maximum integration time was 60 days. Tracing particle travel times, however, allowed for statistical post-processing of the drift simulations according to the assumption of any particle life time being smaller than this maximum integration time.

References

1. Dahlmann, G. & Theobald, N. Öleintrag in die Nordsee. *Wissenschaftlich-Technische Berichte* **4** (1988).

2. Dahlmann, G. et al. Oiled Seabirds-Comparative Investigations on Oiled Seabirds and Oiled Beaches in the Netherlands, Denmark and Germany (1990-93). *Marine Pollution Bulletin* **28**(5), 305–310 (1994).

3. Lozán, J. L., Rachor, E., Reise, K., Sündermann, J. & von Westernhagen, H. *Warnsignale aus Nordsee & Wattenmeer. Eine aktuelle Umweltbilanz* (Wissenschaftliche Auswertungen, Hamburg, 2003).

4. van Bernem, C. & Lübbe, T. *Öl im Meer. Katastrophen und langfristige Belastungen* (Wissenschaftliche Buchgesellschaft, Darmstadt, 1997).

5. Bundesamt für Seeschifffahrt und Hydrographie. *Auswirkungen von Ölkatastrophen durch die Schifffahrt auf die marine Umwelt* (2007). *http : //www.bsh.de/de/Meeresdaten/Umweltschutz/Oelidentifizierung/Tankerunfall.jsp.*

6. Schallier, R., Lahousse, L. & Jacques, T. G. Surveillance aérienne: pollutions marines causées par les navires dans la Zone d' Intérêt de la Belgique en Mer du Nord. Rapport d' activité 1991- 1995. *Unité de Gestion du Modèle Mathematique de la mer de Nord*, 51pp (Bruxelles, 1996).

7. Fleet, D. M. & Reineking, B. Have efforts to clean up the marine environment been successful? - German beached bird surveys provide an index for oil pollution levels in the southern North Sea. Rodriguez, C. R. & Brebbia, C. A. (eds.), *Oil and Hydrocarbon Spills, Modelling, Analysis and Coltrol II*, 117–126 (WIT Press, Southampton, Boston, 2000).

8. Fleet, D. M. & Reineking, B. *Bestimmung, Quantifizierung und Bewertung der Öleinträge in der Nordsee zur Beurteilung der Schiffsentsorgung in deutschen Nordseehäfen*. Bremen, Berlin (2001). FKZ 297 25 310.

9. Camphysen, K. C. J., Fleet, D. M., Reineking, B. & Skov, H. Wadden Sea Quality Status Report 2004. *Wadden Sea Ecosystem* **19**, 115pp (2005).

10. Garthe, S. *Erfassung von Rastvögeln in der deutschen AWZ von Nord- und Ostsee*. Büsum (2003). FKZ 802 85 280 - K1.

11. Fleet, D. M. & Reineking, B. *Analyse und Bewertung der Ergebnisse des Spülsaummonitoring*. Monitroringbericht 2001, Nationalpark Schleswigholsteinsches Wattenmeer, 20–31 (2001).

12. Camphuysen, C. J. & Heubeck, M. Marine oil pollution and beached bird surveys: the developement of a sensitive monitoring instrument. *Env. Poll.* **112**, 433–461 (2001).

13. Dick, S. & Soetje, K. C. *Ein numerisches Modellsystem zur Vorhersage der Drift und Ausbreitung von Öl in der Deutschen Bucht*. Hamburg (1988).

14. Bibby, C. J. & Lloyd, C. S. Experiments to determine the fate of dead birds at sea. *Biology Conservation* **12**, 295–309 (1977).

15. OSPAR Commission. Region II Greater North Sea. *Quality Status Report* 27pp (2000).

16. Golchert, H. & Benshausen, J. *Meeresverschmutzung durch wassergefärdende Stoffe auf See*. Hamburg (1987).

17. Hurrell, J. W. Decadal trends in the north atlantic oscillation: Regional temperatures and precipitation. *Science* **269**, 676–679 (1995).

18. Grimvall, A. & Hallberg, L. *Meteorological normalisation of time series of wet nitrate deposition.* (2002). *http : //www.mai.liu.se/impact/deliverables/Deliverable*7*.html*.

19. Fleet, D. M. et al. PALLAS-Havarie und Seevogelsterben dominieren Spülsaumkontrollen im Winter 1998/99. *Seevögel, Zeitschrift Verein Jordsand* **20**(3), 79–84 (1999).

20. Hervouet, J. M. & van Haren, L. *TELEMAC2D version 3.0 Principle Note.* Chatou CEDEX (1996). Rapport EDF HE-4394052B.

21. Plüß, A. Das Nordseemodell der BAW zur Simulation der Tide in der Deutschen Bucht. *Die Küste* **67**, 83–127 (2004).

22. Kistler, R. et al. The NCEP-NCAR 50-Year Reanalysis: Monthly Means CD-ROM and Documentation. *Bull. Amer. Meteor. Soc.* **82**(2), 247–268 (2001).

23. Meinke, I., von Storch, H. & Feser, F. A validation of the cloud parameterization in the regional model sn-remo. *Journal of Geophysical Research* **109** (2004).

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List of Figures