THE *TRICOLOR* OIL SPILL: AN INCIDENT THAT SHOULD HAVE BEEN PREVENTED

Winter 2002/2003 will be remembered as a black season by those unfortunate enough to become involved in a series of oil spills that killed many tens of thousands of seabirds in West European waters. For most, the *Prestige* spill was by far the most dramatic event and this incident received most media attention. Overshadowed by the *Prestige* in many respects, but arguably at least as harmful to European seabirds, was the *Tricolor* spill that took place in the French Channel. This special issue of *Atlantic Seabirds* is a summary of what we now know about the seabirds killed: how many were affected, what species and of what age they were and their possible breeding origins. It also contains descriptions of the event that made us wonder why it happened in the first place. It attempts to bring together information vital for a proper evaluation of an oil spill and should provide baseline data for future work. This issue has been produced with greatly appreciated financial support from Vogelbescherming Nederland, the Dutch Birdlife partner. As usual, however, most of the work was done by volunteers at their own expense, people concerned enough to become involved.

THE INCIDENT IN BRIEF

The *Tricolor* was not an oil tanker but a freighter carrying cars. The ship sank after a collision in one of the busiest parts of the French Channel, but did not leak much oil initially. Despite buoys and other measures to warn passing vessels, a German coaster and a Turkish tanker collided with the wreck, but these were refloated. Francis Kerckhof, Patrick Roose and Jan Haelters describe what went wrong in their contribution to this issue and indicate that the *Tricolor* only started to leak seriously following salvage operations in January, about a month after the *Tricolor* sank. This salvage work may have been necessary to prevent further collisions between passing vessels and a hazard in a busy shipping lane but had they be postponed until, say, May 2003, the risk to wintering seabirds, most of whom would have vacated the area by May, would have been considerably less. Stienen *et al.* describe the event as it happened in Belgium and their attempts to investigate the effect of the spill by offshore studies in their well-surveyed coastal waters.

SEABIRDS CONTAMINATED WITH OIL

For people who had recently assisted with the impact assessment of the *Prestige* oil spill, reports of a mass stranding of heavily oiled seabirds in the low countries was the last thing that was needed. Despite there perhaps being more experience in oil spill response than in Spain, the initial chaos was substantial and counter-productive steps were taken by regional authorities, such as an immediate removal of oil and oiled birds from beaches before scientists could document the event. One confounding factor was that three (and almost certainly four) countries were involved, with mass strandings occurring almost simultaneously in France, Belgium and The Netherlands and probably South-East England. Despite previous good co-operation between seabird biologists in France, Belgium and The Netherlands, at the time everybody was so busy with the spill that close contacts were only re-established after the event. A post-spill conference in Zeeland in October 2003 and this issue of *Atlantic Seabirds* are the results. It is clear that each and every team approached the problem differently, but partly for good reasons. In France, nearly all casualties were alive when they came ashore. Belgium was overwhelmed by live birds along their coastline at first and was then flooded with dead casualties. In The Netherlands, the mass-stranding was highly localized but most casualties were dead.

MAINLY MATURE BIRDS KILLED

How large the damage has been, we now know quite precisely. Funny enough, that question is asked continuously when it cannot be answered and when all hands are needed on deck: during the spill. Now that the dust has settled, with the autopsy results having been analysed, now that the few rings have been read and processed and with all counts checked and corrected, in fact now everyone has lost interest in the incident, do we have an idea of the damage done: The *Tricolor* killed rather few species, mainly Razorbills and Guillemots, just as the *Prestige*, but as many as 19,000 individuals were found ashore.

	found alive	found dead	Total
N France	2100	3400	5500
Belgium	5300	4200	9500
The Netherlands	700	3300	4000
	8100	10,900	19,000

One significant difference with the *Prestige* casualties was that the auks wintering in the Channel were mainly adults in prime condition (most Common

Guillemots and Razorbills oiled in Spain were first-year birds), so that a more immediate effect on breeding populations might be detected. Biometrics (Kees Camphuysen & Mardik Leopold) and ringing recoveries (Mark Grantham) both suggested that most casualties came from colonies along the east coast of Scotland. Although the return rate of adult Common Guillemots on the Isle of May (Firth of Forth) was below average in 2003 (Mavor *et al.* 2004), no abrupt and substantial declines in numbers were detected at colonies in either eastern England or eastern Scotland in 2003. However, changing fortunes of Common Guillemots and other seabirds in the north-western North Sea for reasons other than oil pollution may "mask" or obscure mass-mortality events such as the Tricolor spill.

IMPACT ASSESSMENT

The work reported in this issue are fruits of the badly needed 'Impact Assessment' of an oil spill, which should be conducted in any incident of this kind. Unfortunately, such impact assessments are still mostly conducted by private individuals concerned enough to drop their normal work and simply do it. In several recent spills, the task of a proper impact assessment has been neglected and the badly needed scientists, government organisations and NGOs often seem too busy to participate or take charge. Apparently, biological impact assessment is considered less important than simply cleaning beaches, and the costs involved in autopsies, no matter how trivial, are still less amenable to compensation from insurers than physical cleanup or rehabilitation efforts. The 'polluter pays' is a good principle, and understanding the potential biological impact of an oil spill should be a part of that payment.

From working in several of the recent oil incidents, it became clear that there is an increasing tendency by the general public, authorities and news media to believe that oil spills don't do long-term damage and that oil-related mortality does not harm seabird populations. These arguments have been used as an excuse by organizations and individuals who do not wish to become involved, and may be fuelled by scientists who cannot detect any long-term effects. These arguments, no matter how slender their factual basis, are happily copied by authorities and insurance companies so that they need not feel utterly concerned. However, in the absence of a rigorous impact assessment (as in most incidents) and with little scientific interest in the aftermath of oil spills, it is impossible to assess the true effects of oil pollution. Any mass-kill of seabirds as a result of ignorance, indifference or bad luck at sea should be properly studied, so that future incidents may be prevented or at least that the impact on wildlife be minimized. At present, the primary concern of most governments is to minimise coastal pollution at all cost, and the *Prestige* spill was a disastrous example of the failure of such an approach. In the *Tricolor* case, the local presence of internationally important concentrations of seabirds was not considered when salvage operations were planned, and this issue is a consequence of that lack of forethought and planning. The *Tricolor* spill could and should have been prevented.

BONUS

No one would hope for an oil spill to take place, but mass mortality incidents such as the kill caused by the *Tricolor* spill do provide useful biological material that should not be wasted. The heavily oiled birds found dead in The Netherlands, that were transported to the Royal NIOZ laboratory for proper identification and ageing, were used to study the winter diets of the most common casualties: Razorbills and Common Guillemots. Ouwehand *et al.* report on the results of this study and took the opportunity to compare the diet of two rather similar, but ecologically quite different seabirds wintering in the Southern Bight. The *Tricolor* provided a rare opportunity to study the diet of these two species in winter from exactly the same location and at the same time of year.

Kees Camphuysen
Editor Atlantic Seabirds

Mavor R.A., Parsons M., Heubeck M., & Schmitt S. 2004. Seabird numbers and breeding success in Britain and Ireland, 2003. UK Nature Conservation No. 28, Joint Nature Conservation Committee, Peterborough, 100pp.

ERRATUM

In Atlantic Seabirds 5(3) on page 97 the photograph does not show a "View of the breeding areas on Rum", but the hills of Canna. The front cover of Atlantic Seabirds 6(1) does not show a Ross's Gull, but an adult Ivory Gull.

SG

THE *TRICOLOR* INCIDENT: FROM COLLISION TO ENVIRONMENTAL DISASTER

FRANCIS KERCHKHOF, PATRICK ROOSE & JAN HAELTERS

Kerckhof F., P. Roose & J. Haelters 2004. The Tricolor incident: from collision to environmental disaster. Atlantic Seabirds 6(3/S.I.): 85-94. *The sinking of the Tricolor on 14 December 2002 and the subsequent related events had disastrous effects on the wintering seabirds in the southern North Sea. This article presents a chronological overview of the events leading to the wreck of seabirds in the first months of 2003 and summarises the actions performed by the administration responsible for marine environmental matters in Belgium, the Management Unit of the North Sea Mathematical Models (MUMM).*

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INTRODUCTION

On 14 December 2002, the car carrier *Tricolor* sank in the eastern Channel area after a collision with the container ship *Kariba*. During this incident, and because of subsequent related incidents involving other ships, hydrocarbons were released into the marine environment, especially from the end of December 2002 to the first months of 2003. Also during salvage operations, chronic pollution occurred in the vicinity of the shipwreck for most of 2003. After an incident on 22 January 2003, during salvage works, the consequences for seabirds became especially apparent. Although the amount of hydrocarbons released was relatively small in comparison with that released during incidents involving tankers such as the *Erika* and the *Prestige*, the consequences for the seabirds wintering off the coasts of northern France, Belgium and the Netherlands proved to be devastating. Many thousands of oiled seabirds washed ashore.

CHRONOLOGICAL DESCRIPTION OF THE INCIDENTS

14 December 2002 On 14 December 2002, around 02:15h UTC, the car carrier *Tricolor* collided with the container ship *Kariba* when both vessels were about to enter into the north-south shipping route through the English Channel. The *Tricolor* turned on its side, and sank in less than half an hour. The position of the shipwreck was 51°22.0’N, 002°12.7’E. This is in the middle of a very busy shipping route in French waters, at approximately 35 km north of Dunkirk, and

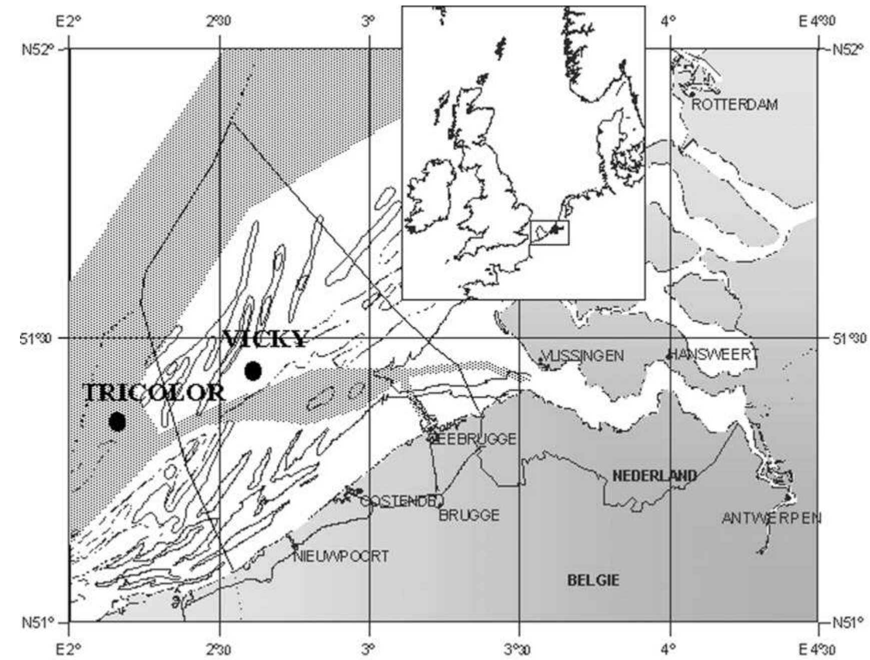

Figure 1. The position of the wreck of the Tricolor*, the Westhinder anchorage area where the* Vicky *remained anchored for nearly two weeks, and the limits of the Belgian marine areas.*

Figuur 1. De positie van het wrak van de Tricolor*, het Westhinder-ankergebied, waar de* Vicky *bijna twee weken voor anker lag, en de begrenzing van de Belgische maritieme wateren.*

near the border of the Exclusive Economic Zones (EEZ) of Belgium and the United Kingdom. (Fig. 1). The *Kariba* steamed back to port, severely damaged. The Norwegian-registered *Tricolor*, built in 1987, traded for the shipping company Wallenius Wilhelmsen lines A.S. The ship was sailing from Zeebrugge to Southampton, carrying, amongst other cargo, almost 3,000 new luxury cars. She had almost 2000 tons of hydrocarbons on board, most of them being heavy fuel. The *Tricolor* was 190 m long and 32m wide, and had a gross tonnage of 49,792 GT. She sank in waters 30 m deep. The *Kariba*, carrying the flag of the Bahamas, was on her way from Antwerp to western Africa, via Le Havre. The crew of the *Kariba* rescued three of the *Tricolor*'s crew members; the remaining 21 crew members found refuge on board the Belgian URS tug *Boxer*. The *Tricolor* was eventually declared a total loss. On 24 December, the

French authorities ordered the wreck to be removed, as it was perceived to represent a danger to shipping and the environment.

16 December 2002 The German coaster *Nicola* ran into the wreck of the *Tricolor*. As the *Nicola* was empty at the time of the collision, she suffered only minor damage. However, the wreck of the *Tricolor* probably suffered further damage.

1 January 2003 The Turkish tanker *Vicky* (244 m long, 43,500 GT), with a cargo of 70,000 tons of gasoline, and more than 2,000 tons of heavy fuel on board, ran into the wreck of the *Tricolor* at full speed. The incident was inexplicable, given the safety measures around the wreck and the warnings for sailors. This collision not only caused much damage to the *Vicky* herself, but also to the wreck of the *Tricolor*. After the collision, the *Vicky* sailed on towards the Westhinder anchorage area, 14 miles off the Belgian coast (at 51°25.4'N, 002°34.9'E; Fig. 1). She leaked hydrocarbons from the ruptured tanks at the bow. The *Vicky* was partly emptied, and left the anchorage area only on 12 January. Between 2 and 8 January, more than 200 oiled birds were taken to the permanent rehabilitation centre at Oostende. Most probably these birds were fouled with oil originating from the *Vicky*.

22 January 2003 During operations aimed at emptying the fuel tanks of the *Tricolor*, in which the tug *Alphonse Letzer* participated, two valves on one of the fuel tanks of the *Tricolor* broke loose. Probably up to 170 tons of heavy fuel escaped rapidly into the sea. Clean-up operations at sea proved impossible during the following days because of poor weather.

22 January to mid-February During pollution control flights by the Management Unit of the North Sea Mathematical Models (MUMM), limited but chronic leakage of oil was observed from the wreck of the *Tricolor*. Probably more than 170 tons of oil were released into the sea from 22 January onwards, as it became clear by mid February that the wreck had suffered important structural damage, and that several of the fuel tanks were ruptured. According to a press release of the *Préfecture Maritime de la Manche et de la Mer du Nord*, most of the oil had been pumped out of the wreck by 17 February, but up to 60 tons of oil might still have been present in the wreck.

In contrast with the situation during the first weeks of January, strong onshore winds prevailed between the last week of January and the first weeks of February. This resulted in very high numbers of oiled seabirds on beaches in France, Belgium and the Netherlands (Haelters *et. al*. 2003; Stienen *et al*. 2004, this issue).

The giant sheerlegs (floating cranes) Asian Hercules *II and* Rambiz *have lifted the first section of the* Tricolor *and placed it on the floating pontoon* Giant 4. De drijvende kranen *Asian Hercules II* en *Rambiz* hebben het eerste deel van de *Tricolor* opgetild en op de drijvende Giant 4 geplaatst *(photo MUMM).*

22 July 2003 – September 2004 The salvage operation of the giant wreck of the *Tricolor* was one of the largest ever attempted. A Dutch-Belgian consortium *Combinatie Berging Tricolor* (CBT) started cutting-up the wreck into nine sections, using a special steel-cutting wire system operated from two working platforms (see picture). A similar technique was used before during the salvage of the wreck of the Russian submarine *Koersk*. The sections of the *Tricolor* were lifted out of the water with two sheer-leg cranes, and put onto a barge for transportation to Zeebrugge, where they were scrapped together with their content.

The cutting and dismantling of the wreck began on 22 July and continued through the summer of 2003. The eighth and final cut was completed on 17 October. On 12 November 2003, unfavourable weather conditions necessitated postponement of the removal of the remaining sections. By then, five sections of the wreck had been lifted and transported to Zeebrugge. Severe, gale force winds rendered the removal of the four remaining sections too dangerous. These sections, weakened due to the cutting operations and the poor weather conditions, had collapsed. It was possible to remove them only by using a floating crane equipped with a large grab. This was done during summer 2004. The whole operation, including the removal of all scrap from the seafloor was completed in October 2004.

Oil pollution during the summer of 2003 During the salvage operations, the wreck still contained quantities of oil. The owners of the *Tricolor* estimated that 490 tons of heavy fuel had not been recovered during pumping operations. Analyses of the oil that was recovered from the wreck revealed that it had formed an emulsion with 30-50 % water.

During cutting and lifting actions, a significant quantity of heavy fuel was released from the wreck on 6 and 7 September. During the following weeks, this oil polluted large parts of Belgian and French waters and coastline. During aerial surveys conducted by MUMM, estimates of the quantity of emulsified oil observed at sea ranged from 200-800 tonnes. This was apparently the last major release of oil from the wreck. Given the low numbers of vulnerable birds in this region during this time of the year, the oil released during this incident probably did not cause a high number of casualties amongst birds.

ACTIONS PERFORMED BY MUMM/RBINS DURING THE *TRICOLOR* INCIDENT

The Management Unit of the North Sea Mathematical Models (MUMM) is a department of the Royal Belgian Institute of Natural Sciences (RBINS), a federal scientific institute. MUMM, as the administration responsible for marine environmental matters in Belgium, had the task of continuously assessing the environmental impact of this incident. The resources available to MUMM include a dedicated aircraft, mathematical models, a laboratory, and an intervention network for dealing with stranded animals, in which a large number of institutes and organisations participate.

MUMM operates, in co-operation with the Belgian army, a twin engined Britten Norman Islander equipped for tracking and recording oil pollution. This aircraft is also used as a guide for ships controlling pollution on the sea surface. During the *Tricolor* incident, frequent pollution control flights were carried out over Belgian waters and over the wreck site in French waters. Observations of oil pollution were reported to relevant authorities (Coastguard, Flemish Community, coastal Province, French authorities) on a regular basis, and were fed into the mathematical models run by MUMM.

Mathematical models describing the movement, spread, and physical and chemical development of pollutants, particularly hydrocarbons, were used to determine the potential impact of pollution, and to provide support for decisions to be taken in pollution control operations. In order to run, the model requires the input of the spill co-ordinates, the volume of the spill, the nature of the oil, water current data, and meteorological conditions. One of the models used is the so-called MU-slick model (MUMM 2004). This model is particularly useful

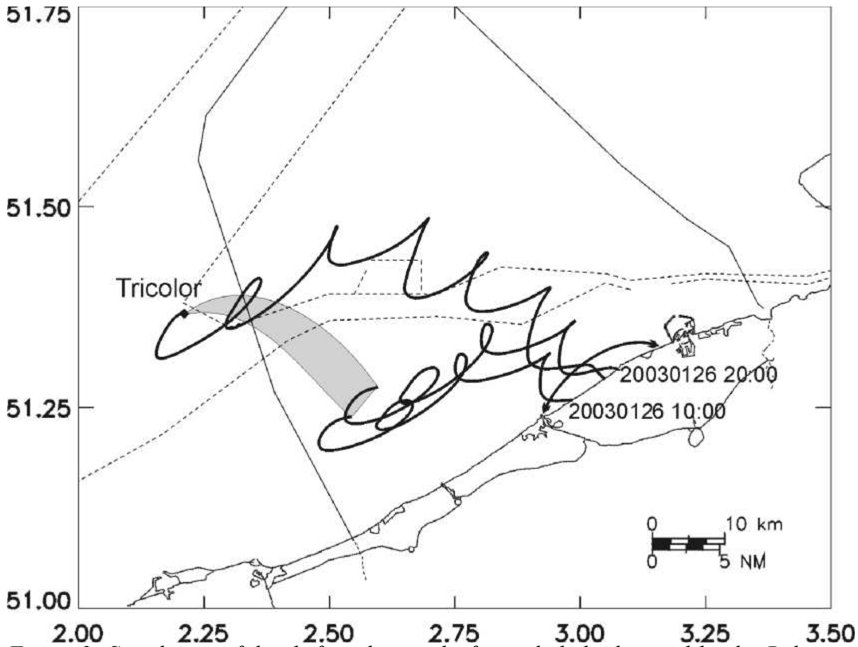

Figure 2: Simulation of the drift and spread of an oil slick observed by the Belgian surveillance aircraft on 24 January 2003 (grey zone). On 24 January the model predicted that oil would wash ashore from 26 January onwards, between Oostende and Zeebrugge. The end of the simulation was 28 January 2003. Such simulations were repeated every few hours with the input of the most recent meteorological predictions (source S. Scory, MUMM).

Figuur 2. Simulatie van de verspreiding en groter worden van een olievlek die 24 januari 2003 door een Belgisch surveillance-vliegtuig werd waargenomen (grijs). Op 24 januari voorspelde het model dat de olie vanaf 26 januari tussen Oostende en Zeebrugge zou aanspoelen. De simulatie eindigde op 28 januari 2003. Deze simulatie werden om de paar uur herhaald met input van de meest recente meteorologische verwachtingen (bron S. Scory, MUMM).

when there is a risk of oil pollution on the shore. Figure 2 shows a simulation of the drift and spreading of an oil slick as an example.

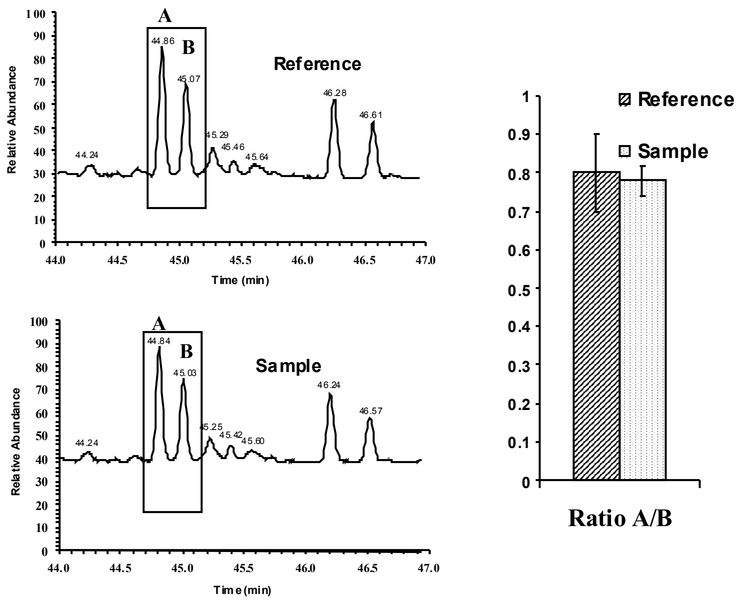

Figure 3. Comparison between the hopane pattern of a sample and a reference oil, including the illustration of the calculation and comparison of diagnostic ratios.

Figuur 3. Vergelijking van het hopaanpatroon van een monster en een referentie, inclusief een beeld van de berekening en vergelijking van diagnostische verhoudingen.

Intervention network for dealing with scientific research on stranded animals Since 1992, MUMM has co-ordinated scientific research on stranded marine mammals and seabirds. This includes regular counts of stranded seabirds, carried out by the Institute of Nature Conservation (Seys 2001). Given that the number of stranded seabirds during the last week of January and the first weeks of February 2003 reached such high numbers, MUMM requested the coastal communities to transport not only live birds, but also dead birds to the ad-hoc rehabilitation centre at Oostende. There, all dead birds were identified and counted by personnel of MUMM, the Institute of Nature Conservation and volunteers of the Bird Rehabilitation Centre at Oostende (VOC). Live birds were counted, identified and cared for by hundreds of helpers and volunteers of the VOC. Detailed results of these counts appear in Haelters *et al.* (2003), and are also discussed in Stienen *et al.* (2004, this issue). A report on the extensive rescue operation was published by the VOC (Velter 2003).

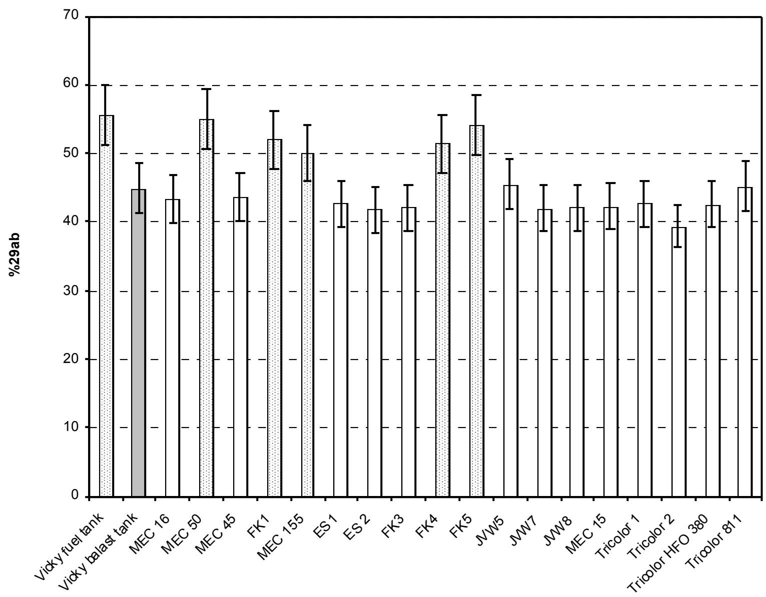

*Figure 4. Comparison of the percentage of biomarker 29ab in oil samples collected during the incident and reference samples (*Vicky*: light and dark grey,* Tricolor*: white). Error margins represent the 95% CI of the calculated value.*

*Figuur 4. Vergelijking van het percentage van de biomarker 29ab in oliemonsters die verzameld zijn tijdens het incident met referenties (*Vicky*: lichtgrijs en donkergrijs,* Tricolor*: wit). Foutenmarges geven de 95%-betrouwbaarheidsinterval van de berekende waarde aan.*

Laboratory analyses Oil is a complex chemical mixture. Several of its constituents can be used for identification purposes: polyaromatic hydrocarbons (PAHs) and the so-called biomarkers. Biomarkers, such as hopanes, are molecules of biological origin that are characteristic of the region where the oil was formed. Oils from different oil fields therefore have a different PAH and/or biomarker pattern. Moreover, these particular chemicals are resistant to degradation, rendering the patterns constant over time. During the incident, MUMM, together with other authorities such as the Coastguard, the Flemish Community and local authorities, took samples of the oil on beaches, on birds, at sea, and from the wreck itself. The French authorities provided reference samples of oil from the bunkers of the *Tricolor*, and also reference samples of oil from the *Vicky* and the *Prestige*. These samples were taken to MUMM's laboratory in Oostende for comparative analysis.

At the MUMM laboratory, a selected number of oil samples were analysed, and the relative abundance of PAHs and biomarkers in each of them was calculated (Fig. 3). The ratios between two oil components shown in the box in Fig. 3 (known as the diagnostic ratios for marker compounds) are statistically compared with those for an unknown sample and a reference sample. An unknown sample was considered to be different from the reference sample if the value for the selected diagnostic ratio (DR) was outside the 95% confidence intervals (CI) of the DR for the reference sample. Figure 4 shows the comparison of the DRs for biomarker 29ab, calculated for the reference samples and the unknowns. From the graph, samples originating from the *Vicky* (light grey) can easily be identified. On the other hand, no distinction could be made between a sample containing oil from the ballast water tank of the *Vicky* (dark grey) and samples from the *Tricolor* (white). This clearly illustrates the possibilities and the pitfalls of oil fingerprinting during an incident such as this one.

CONCLUSIONS

Dealing with a disaster such as the Tricolor inherently requires the deployment of a great deal of manpower and resources. Although the treatment and rehabilitation of oiled wildlife was of major importance, many other problems had to be tackled as well. This could only be achieved by close co-operation between all involved parties. In many ways, the co-operation between the various official bodies, NGOs and the numerous volunteers was remarkable and highly stimulating. Meanwhile, during multidisciplinary research, data were collected on all aspects of the incident. The research yielded valuable data needed for the assessment of the potential ecological consequences. The results will also allow authorities to be better prepared for future disasters. Finally, the scientific results play an important role in raising public awareness.

HET TRICOLOR INCIDENT: VAN AANVARING TOT MILIEURAMP

Het zinken van de Tricolor op 12 december 2002 en de daaropvolgende incidenten hebben een zware milieuramp veroorzaakt met verstrekkende gevolgen voor de zeevogels die overwinteren in Het Kanaal. In dit artikel wordt een chronologisch overzicht gegeven van de gebeurtenissen die voorafgingen aan de stranding van olieslachtoffers op de Franse, Belgische en Nederlandse kust gedurende de eerste maanden van 2003. Daarnaast wordt een overzicht gegeven van de activiteiten van één van de verantwoordelijke autoriteiten in België tijdens het Tricolor incident, namelijk de Beheerseenheid van het Mathematisch Model van de Noordzee (BMM, Koninklijk Belgisch Instituut voor Natuurwetenschappen).

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The multipurpose offshore salvage and diving support vessel Union beaver *is specially equipped to clean up oil from the sea.* Het multifunctionele offshore bergingsvaartuig *Union beaver* is speciaal uitgerust om olie van het zeeoppervlak op te ruimen (*photo MUMM).*

AGE STRUCTURE AND ORIGINS OF BRITISH & IRISH GUILLEMOTS *URIA AALGE* RECOVERED IN RECENT EUROPEAN OIL SPILLS

MARK GRANTHAM

Grantham M.J. 2004. Age structure and origins of British & Irish Guillemots *Uria aalge* recovered in recent European oil spills. Atlantic Seabirds 6(3/S.I.): 95-108. *Following several recent major oil spills affecting British & Irish breeding Guillemots Uria aalge, I carried out analyses of the origin of ringed birds recovered following these incidents to describe the importance of different wintering areas for this species. The results show significant differences in the age structure and natal origin of birds affected in the different oil spills, indicating the existence of different wintering areas for different breeding populations of Guillemots. Birds wintering in the south western approaches to the English Channel and south into the Bay of Biscay (affected by the Prestige spill) tended to be immature birds from colonies in the west of Britain and Ireland, whereas birds wintering in the English Channel and North Sea (affected by the Tricolor spill) tended to be adults from colonies in eastern Britain. In general, immatures appear to winter further from their natal colony than adults. By understanding the dispersal patterns and winter distribution of such birds, we can assess the likely impacts on bird populations of pollution incidents.*

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INTRODUCTION

With increased sea transport of petroleum products, there is always the risk of oil spills at sea. In the 1960s, the number of oil spill incidents rose markedly, though the number of incidents has been reduced by tighter controls on shipping since the late 1970s. However, the larger size of modern tankers means that any incident will potentially result in a larger oil spill and hence greater environmental problems. The Guillemot *Uria aalge* is usually the species most affected by large-scale oil spills, with many oiled birds eventually washing up on beaches (Baillie & Mead 1982).

Britain & Ireland have a substantial percentage of the European breeding population of Guillemots (Lloyd *et al*. 1991), though little has been published of the wintering areas of specific populations. Analyses of ring recovery data (Harris & Swann 2002) show that immature birds appear to winter further from breeding colonies than adults, but this is a general assumption, with no detail for individual colonies or populations. It is essential to understand which areas are

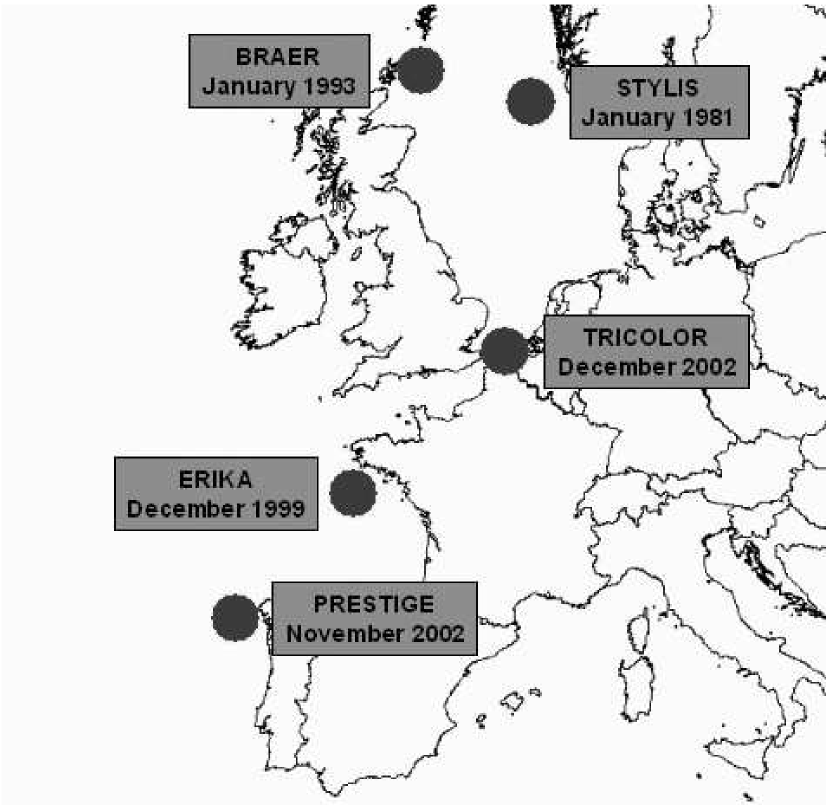


Figure 1. Locations and dates of recent major oil spills in European waters.
Figuur 1. Locaties en data van recente grote olieverontreinigingen in Europese wateren.

important to the birds outside of the breeding season if we are to ensure their long-term protection.

In November 2002, the tanker *Prestige* sank off the coast of Galicia, Spain, and the following month the tanker *Tricolor* sank in the English Channel. Following these spills, the British Trust for Ornithology (BTO) received many reports of ringed birds (both dead and alive) that had been found on beaches. To assess the impact of the two spills, I describe the features of the population(s) of birds affected by five recent oil spills in European waters.

METHODS

Selection of recoveries Recoveries (found either dead or alive) of BTO-ringed Guillemots after five major oil spills in European waters were used to investigate the age structure and origin of the birds affected by the spills. These were from the vessels *Stylis* (North Sea, January 1981), *Braer* (Shetland, UK, January 1993), *Erika* (Brittany, France, December 1999), *Prestige* (Galicia, Spain, November 2002) and *Tricolor* (Netherlands, December 2002) (Fig. 1).

Recoveries of birds were initially selected where the birds were noted as being oiled, and the finding date fell shortly after each spill date. The period after the spill when reports were selected was judged by eye from recovery totals shown by week. The finding locations of the birds were plotted and I identified which recoveries were likely to relate to each particular oil spill, based on proximity to the spill site, with those in adjacent coastal areas selected for analyses. For example, recoveries of oiled birds following the *Prestige* spill spread from the Galician coast near the spill site along the coast of the Bay of Biscay to southern France (Fig. 2). The selection of recoveries may have included some that were unrelated to each individual oil spill, though this number will have been small. The total number of filtered recoveries from each of the five major spills is shown in Table 1, and recoveries from each spill were then analysed separately.

From each spill sample, birds were initially grouped by age class. Most Guillemots do not return to breeding colonies until after their second year (Cramp 1985), though some studies (i.e. Harris et al 1994) have shown that many birds will not actually breed until they are six years old. Where possible, birds were classed as immatures (first and second year birds) or breeding age birds (third year birds and older). The majority of Guillemots had been ringed as chicks so this allowed the birds to be classified as immatures (found less than two years after ringing) or adults (found more than two years after ringing). The birds not ringed as nestlings were classed as adults if they were found more than a year after ringing. Not all birds ringed when fully-grown could be assigned to an age class, as many were of unknown age when ringed and found soon after ringing. These birds were therefore excluded from all analyses of age structure. Differences in the age classes between adjacent spills were tested using chi-square tests of association.

Effects of ringing place Birds of known breeding origin were selected from the full dataset for each spill. This dataset included only those birds ringed as nestlings or those that were ringed as breeding adults (actively nesting or in a colony). Colonies were then grouped into four geographical areas (Fig. 3):

– Wales and Ireland

Table 1. Number of BTO-ringed Guillemot reported following five large European oil spills, and the total number of BTO-ringed casualties
Tabel 1. Aantal met BTO-ringen geringde Zeekoeten die werden doorgegeven na Europese olieverontreinigingen, en het totaal aantal BTO-slachtoffers.

	Stylis	Braer	Erika	Prestige	Tricolor
Number of Guillemot reported	33	15	230	98	45
Total number of BTO-ringed birds reported	51	73	267	149	71

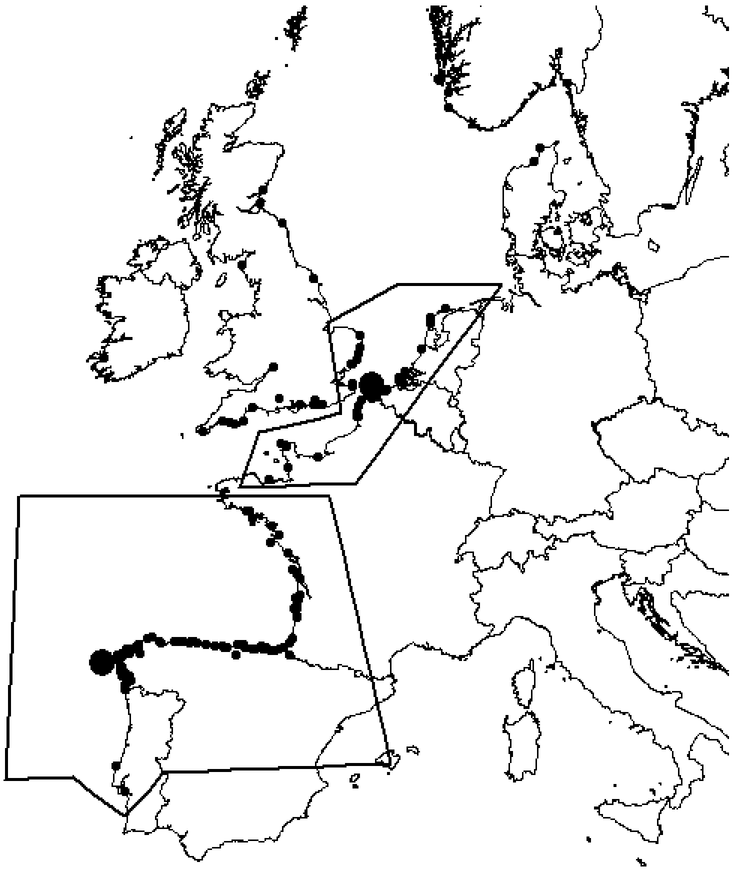


Figure 2. Geographical selection of ringing recoveries relating to the Tricolor *and* Prestige *oil spills by finding location.*
Figuur 2. Geografische selectie naar vindplaats van ringvondsten gerelateerd aan de Tricolor *en* Prestige *olieverontreiniging.*

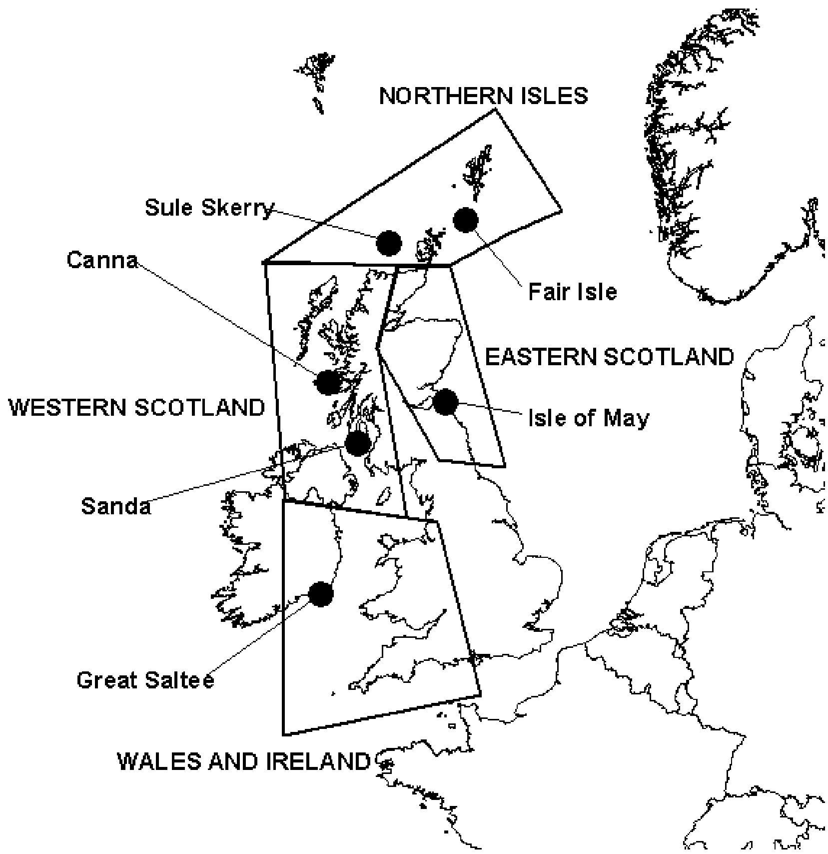


Figure 3. Location of six main seabird colonies used for population analyses and the boundaries used to define geographical areas for analyses.
Figuur 3. Ligging van de zes belangrijke zeevogelkolonies die werden gebruikt voor de analyses en de begrenzing van de gebieden die voor de analyses gebruikt werden..

– Western Scotland (including the Western Isles and coastal locations between Dumfries and Cape Wrath)
– Northern Isles (Shetland, Orkney, Sule Skerry and North Rona (politically part of the Western Isles, but geographically closer to the Northern Isles))
– East Scotland (from Caithness south to the Firth of Forth)

Differences in the origins of birds found in the different spills were tested using chi-square tests of association.

To assess the impact of the spills on different colonies, I estimated the number of Guillemots killed from the main colonies in Britain & Ireland in each spill (Fig. 3). Colonies were selected with a long run of both annual ringing totals and colony count data. Count data were provided by JNCC from the Seabird 2000 survey results (Mitchell *et al*. 2004) and the Seabird Colony Register (R. Mavor pers. comm.) I also only considered birds ringed as nestlings, as I had to use annual productivity (of nestlings) as a measure of birds entering the population. This was not considered to be a major bias in the data as a large majority of Guillemots (>80%) are ringed as nestlings (Clark *et al*. 2002).

For each spill and each colony I calculated the number of birds recovered from each annual cohort of ringed nestlings. Using the annual ringing totals (of nestlings) for each colony, I calculated the proportion of the ringed cohort from each year that had been found in the spill. For each breeding season at each colony, I then knew the proportion of ringed nestlings that were recovered following each spill. Assuming that the same factors affect ringed birds as unringed birds, the proportion of ringed birds found can be estimated to give the minimum number of birds affected (see Appendix 1 for calculations).

RESULTS

The number of BTO-ringed birds reported following each of the five spills is shown in Table 1. The *Erika* and *Prestige* spills resulted in the largest numbers of recoveries, with Guillemots making up a large proportion (69%) of this overall total.

The age distribution of known-age Guillemots from each of the five large spills is shown in Fig. 4. Those reported following the *Prestige* spill were predominantly immatures (89%) whilst those from the *Tricolor* spill were predominantly adults (79%, Table 2). Following the *Erika* spill, 58% of birds recovered were immatures, significantly different from both the *Prestige* and *Tricolor* spills. Following the *Stylis* and *Braer* spills, 87% and 77% (respectively) of ringed birds found were immatures, a difference that was insignificant.

Table 2. χ^2 results and significance levels for comparing the ages of BTO-ringed Guillemots reported following five large European oil spills (*** p<0.0001; ** p<0.001; * p<0.01). Sample sizes are shown in Table 1

Tabel 2. Vergelijking van de leeftijd van Zeekoeten met BTO-ringen die werden gemeld na vijf grote Europese olieverontreinigingen, met een χ^2-toets. (*** p<0.0001; ** p<0.001; * p<0.01). Steekproefgroottes staan in tabel 1.

	Braer	Stylis	Tricolor	Erika
Prestige	1.56	0.10	60.65***	84.45***
Erika	1.85	9.80*	18.58***	-
Tricolor	13.52**	30.77***	-	
Stylis	0.71	-		

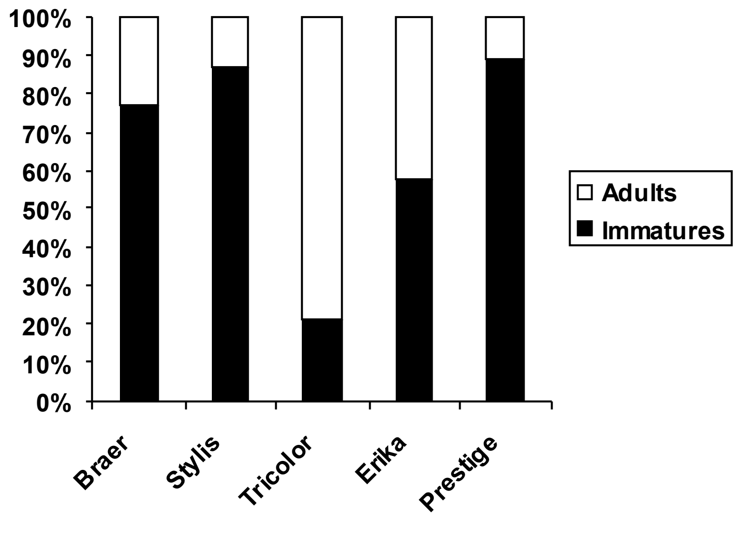


Figure 4. Proportion of immature and adult Guillemots found following five large oil spills. Sample sizes are given in Table 1

Figuur 4. Aandeel onvolwassen en adulte Zeekoeten die werden gevonden na vijf grote olieverontreinigingen. Steekproefgroottes staan in tabel 1.

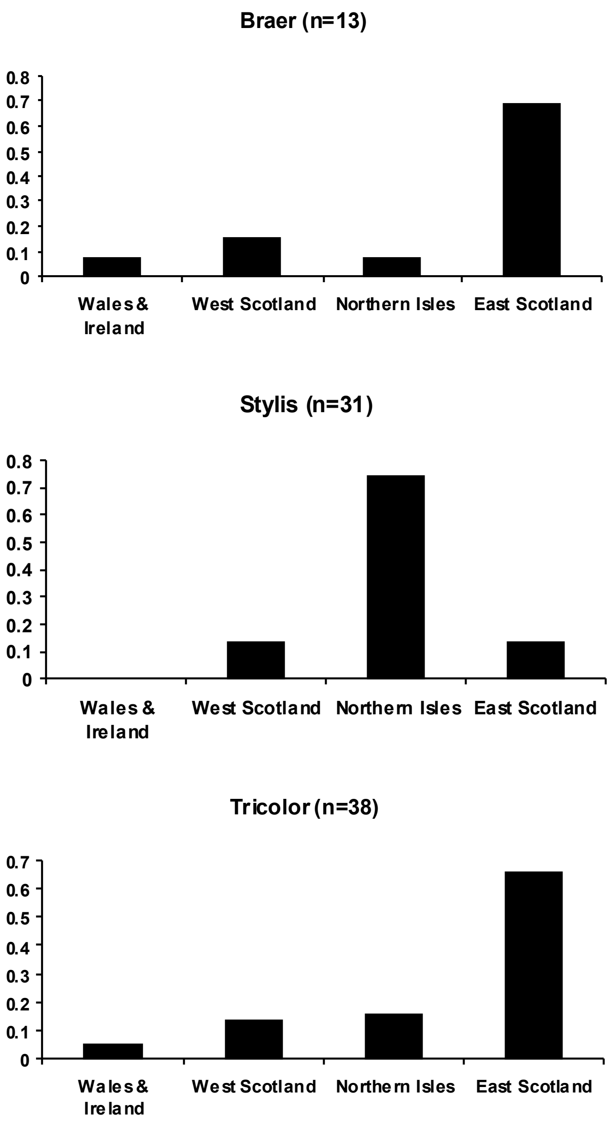
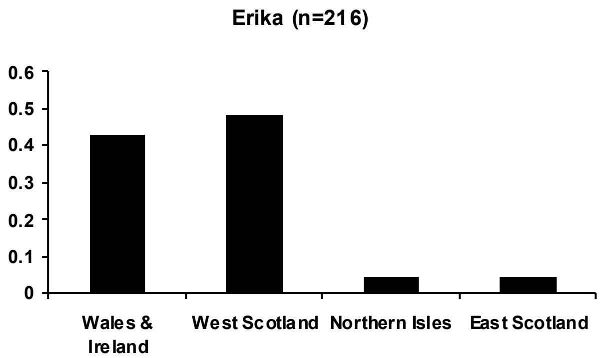
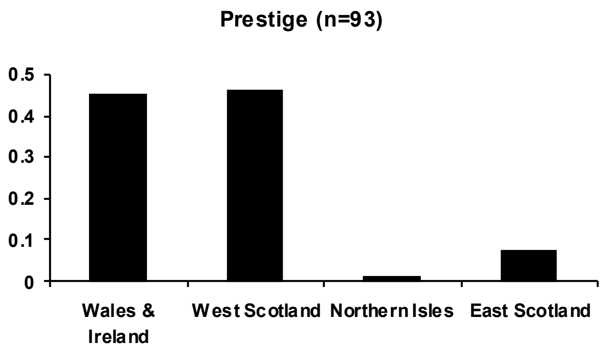


Figure 5. See opposite page for legend.
Figuur 5. Zie tegenoverliggende pagina voor bijschrift.





This page and opposite page: figure 5. Proportions of Guillemots originating from four geographical areas found following five major oil spills.
Deze pagina en tegenoverliggende pagina: figuur 5. Geografische verdeling van Zeekoeten die werden gevonden na vijf grote olieverontreinigingen.

The origins of the birds found following each spill also varied significantly. A large proportion (91%) of birds found following the *Prestige* spill originated from colonies along the western coasts of Britain and Ireland (Fig. 5), whereas those found after the *Tricolor* spill originated from colonies in eastern Scotland (66%); a significant difference (Table 3). Birds found following the *Erika* spill originated from colonies similar to *Prestige* birds, though significantly different from *Tricolor* birds. Birds from the *Stylis* spill originated predominantly from the Northern Isles, significantly different to the east Scottish origin of *Braer* birds.

*Table 3. χ^2 results and significance levels for comparing the origins of BTO-ringed Guillemots reported following five large European oil spills (*** p<0.0001; ** p<0.001; * p<0.01). Sample sizes are shown in Table 1*

*Tabel 3. Vergelijking van de herkomst van Zeekoeten met BTO-ringen die werden gemeld na vijf grote Europese olieverontreinigingen, met een χ^2-toets. (*** p<0.0001; ** p<0.001; * p<0.01). Steekproefgroottes staan in tabel 1.*

	Braer	Stylis	Tricolor	Erika
Prestige	1176***	383***	537***	3163
Erika	1613***	1164***	1190***	-
Tricolor	803	2292***	-	
Stylis	1880**	-		

Table 4. Estimated minimum numbers of birds from five large colonies affected by three large oil spills

Tabel 4. Geschat minimum aantal vogels afkomstig van vijf grote kolonies die door drie grote olieverontreinigingen zijn getroffen.

	Fair Isle	Great Saltee	Canna	Isle of May	Sule Skerry	Sanda	TOTAL
Prestige		185	22	89	29	33	358
Erika	54	333	44	99	37	40	607
Tricolor		10		126	28	5	169

In both the *Tricolor* and *Prestige* spills, there was also a tendency for all immature birds to originate from western colonies, whereas adult birds originated from eastern and northern colonies. Unfortunately the sample sizes of known-age, known-colony birds were too small to carry out statistical analyses.

The estimates of total number of birds killed in each colony further highlighted the differences between the spills (Table 4). These figures also show an easterly bias to the origin of birds found following North Sea spills. For birds ringed on the Isle of May, an estimated minimum of 126 birds were probably affected by the relatively small *Tricolor* spill, with only 99 affected by the much larger *Erika* spill further to the south. From such spills further south, birds affected originated from more westerly colonies (e.g. Great Saltee Island).

DISCUSSION

Guillemots are regularly the species most affected by large oil spills in the North Sea and adjacent waters, and the spills considered here were no exception, with large numbers of ringed birds being reported to the BTO.

As the birds from each colony are though to winter in different areas (Harris & Swann 2002), the population (or particular part of the population) of Guillemots affected by an oil spill depends on its location. The significant differences between the age structure and origin of the birds found between the spills are similar to those of previous analyses of BTO-ringed birds. This showed that, on average, immature Guillemots were recovered 587km from their initial ringing location, whereas adult birds were reported on average only 357km distant (Harris & Swann 2002). It is thus not surprising to find a larger number of immature birds further south into the Bay of Biscay than in the English Channel or North Sea.

The significant differences between both the age class and origin of recovered Guillemots following the three more southern spills (*Tricolor*, *Erika* and *Prestige*) were interesting. Birds found after the two spills in the Bay of Biscay were predominantly immatures from colonies in the west of Britain and in Ireland, whereas birds found after spills further north into the English Channel were predominantly adults from colonies in the east of Britain. It appears that in the winter, birds from eastern colonies do not penetrate to sea areas beyond the English Channel, but winter in more northern areas. Birds from more western colonies winter in these southern areas, with immatures tending to winter further south. This may explain why we see a significant difference between the age structure of *Erika* and *Prestige* birds, but no difference in their origin.

In the North Sea, the pattern was not so clear, though a high proportion of Guillemots recovered after North Sea and English Channel spills originated from colonies in eastern Scotland and the Northern Isles. In general, birds recovered further north were more likely to be immatures, whereas those recovered further south in the North Sea were more likely to be adults. Interestingly, the two adjacent spills in the North Sea (*Braer* and *Stylis*) occurred at a similar time of year, but lead to recoveries of birds from significantly different areas. Birds found after the *Stylis* spill originated from colonies in the Northern Isles, whilst those from the *Braer* spill (which occurred in the Northern Isles) originated from eastern Scotland.

The calculations of the estimated minimum numbers of birds affected by the three largest spills can give an indication of the possible impact on these breeding colonies. What is of most interest is the age structure of those birds killed. Knowing that most birds in the English Channel in winter are likely to be adults, any pollution incident will have a very direct impact on the numbers of returning breeding birds to eastern colonies. The effect of a spill further south will be less severe, as this would be expected to affect mostly immature birds that have not yet entered the breeding population. In this case, unless a very high proportion of an age class died, it is less likely that a population effect would be found as the mortality could be compensatory rather than additive. If the mortality is compensatory, the same number of birds would still be available to enter the breeding population in later years.

ACKNOWLEDGEMENTS

The BTO is indebted to all of its volunteer ringers who annually visit seabird colonies to ring thousands of birds. I thank all of the volunteers who religiously reported ringed birds back to us allowing these analyses to be carried out, especially Rubén Moreno-Opo Díaz-Meco from the Ministerio de Medio Ambiente in Spain. Thanks also to Roddy Mavor of the JNCC seabird team for supplying colony count data and to Jacquie Clark and Rob Robinson for comments on earlier drafts of the paper.
The BTO Ringing Scheme is funded by a partnership of the British Trust for Ornithology, the Joint Nature Conservation Committee (on behalf of English Nature, Scottish Natural Heritage and the Countryside Council for Wales, and also on behalf of the Environment and Heritage Service in Northern Ireland), National Parks and Wildlife (Ireland) and the ringers themselves.

LEEFTIJDSSAMENSTELLING EN HERKOMST VAN BRITSE EN IERSE ZEEKOETEN GEVONDEN TIJDENS RECENTE EUROPESE OLIERAMPEN

Na diverse recente grote olieverontreinigingen die invloed hadden op Zeekoeten *Uria aalge* broedend in Groot-Brittanië en Ierland, heb ik onderzoek gedaan naar de herkomst van de geringde vogels die werden gemeld tijdens deze incidenten. Doel hiervan was het beschrijven van het belang van de verschillende overwinteringsgebeiden voor deze soort. De resultaten laten significante verschillen zien in leeftijdsamenstelling en herkomst van broedvogels die betrokken waren bij de verschillende olieverontreinigingen. Dit wijst op het bestaan van verschillende overwinteringsgebieden voor verschillende broedpopulaties. Overwinteraars in de 'Southwestern Approaches' en zuidelijker in de Golf van Biskaje (betrokken bij de *Prestige*-ramp) waren over het algemeen onvolwassen vogels van kolonies in het westen van Groot-Brittannië en Ierland. Overwinteraars in het Kanaal en de Noordzee (betrokken bij de *Tricolor*-ramp) waren over het algemeen adulte vogels uit kolonies in het oosten van Groot-Brittannië. Generaliserend, onvolwassen vogels leken verder van hun (geboorte)kolonies te overwinteren dan adulte vogels. Door een beter begrip van de dispersiepatronen en overwinteringsgebieden van dergelijke vogels kunnen we inschatting maken van de mogelijke invloed van olierampen op populaties.

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Appendix 1. Estimating numbers of birds from main colonies affected by each spill

To estimate the numbers of birds from Great Saltee affected by the Erika spill, we need to know the number of birds recovered from each annual cohort, the number of birds ringed each year and the colony size in those years.

To calculate the total number of birds affected, we need to calculate the proportion of birds ringed in each year that were later recovered in the spill:

Proportion of birds recovered = number recovered / total number ringed
e.g. From the 1999 cohort, the proportion of birds recovered = 28 / 1,799 = 0.01556

This figure can then be extrapolated by multiplying by the number of nestlings fledged from the colony. This is calculated using population figures (in number of individual adults counted) from Seabird 2000. This figure is multiplied by 0.67 to give the number of occupied sites (AOS) (see Lloyd *et al.* 1991), and then multiplied by 0.8 (productivity per nest), to give a measure of annual productivity. A figure of 0.8 chicks per pair was used for productivity as Cramp (1995) shows figures from several studies of productivity ranging from 0.75-0.85.

Nestlings fledged from colony = number of individuals counted x 0.67 x 0.8
For the 1999 example, nestlings fledged from colony = 19,700 x 0.67 x 0.8 = 10,559

Assuming the same factors affect ringed and unringed birds, we can extrapolate the data for ringed birds to the whole population (ringed and unringed), and estimate the total number of birds affected:

Number affected = proportion of ringed birds recovered x number fledged
In the 1999 example, number affected = 0.01556 x 10,559 = 164

This same calculation is then run for each year where ringed birds were recovered, giving a minimum estimate of mortality for the whole colony.

Ringing year	Number of cohort recovered	Number ringed	Number of individuals in colony	Total number affected
1981	1	1,775	16,963	5
1985	1	1,822	16,963	5
1992	1	2,541	15,600	3
1993	1	2,998	15,000	3
1994	9	2,799	14,584	25
1995	4	2,798	15,700	12
1996	7	2,791	16,936	23
1997	3	2,316	17,600	12
1998	18	2,174	18,274	81
1999	28	1,799	19,700	164
TOTALS	73			333

THE *TRICOLOR* OIL SPILL: CHARACTERISTICS OF SEABIRDS FOUND OILED IN THE NETHERLANDS

C.J. CAMPHUYSEN[1,2] & M.F. LEOPOLD[2,3]

Camphuysen C.J. & M.F. Leopold 2004. The *Tricolor* oil spill: characteristics of seabirds found oiled in The Netherlands. Atlantic Seabirds 6(3/S.I.): 109-128. *Between 28 January and 9 February 2003, c. 4000 heavily oiled seabirds washed ashore in The Netherlands, representing 21% of c. 20,000 casualties of the* Tricolor *oil spill recovered in northern France, Belgium and The Netherlands. Common Guillemot* Uria aalge*, Razorbill* Alca torda *and Black-legged Kittiwake* Rissa tridactyla *together represented 91% of the birds found and collected. Nearly 600 Common Guillemots and 267 Razorbills were examined in more detail and a large part of these birds were dissected. Autopsies revealed that the auks were in excellent condition when they died, indicating instant death through suffocation in oil. Of 440 Guillemots that could be aged, 76% were mature birds, with a sex ratio significantly different from equal (65% males). Of 262 Razorbills, 77% were adults and 62% were males. Biometrics suggested that the Guillemots belonged to the nominate subspecies, whereas the Razorbills were classified as* A.t. islandica*. Using the European cline in wing length, the Guillemots possibly originated from Scottish colonies (57°N), a finding that was supported by ringing recoveries (Scottish east coast). The total mortality caused by the* Tricolor *spill, 2-5 times the number of casualties recovered, may be estimated at 40 000-100 000 seabirds (25 000-62 500 Guillemots, 8000-20 000 Razorbills). With such a high proportion of mature birds in excellent pre-breeding condition being killed, an immediate effect on the breeding population is foreseen, rather than a diffuse and delayed effect if more immatures would have been killed. It is argued that effect of the* Tricolor *on seabirds would have been considerably less, had the salvage operation be postponed till summer. The Channel area is of the highest vulnerability to oil pollution only in winter (Dec-Mar).*

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INTRODUCTION

The *Tricolor*, a Norwegian flagged vehicle carrier built in 1987, sank on 14 December 2002 some 25 km north of the French coast in the English Channel (51°21.9'N, 02°12.6E) as a result of a collision with the *Kariba*, a Bahamian flagged container ship built in 1982. The collision occurred when both vessels were about to enter into the north-south shipping lane through the English Channel. The *Tricolor*, struck by the *Kariba* on port side, capsized and sunk within 30 minutes. Two days later, on 16 December 2002, the unloaded German cargo vessel *Nicola* hit the wreck of the *Tricolor*. Tugs pulled the cargo ship from the wreck on the same day. Around this time, French authorities ordered the *Tricolor* to be removed, as it was perceived to represent a danger to shipping and the environment. On 1 January 2003, the *Tricolor* was struck again, this time by the Turkish tanker *Vicky*, carrying 77 000 tons of gas oil. It was only on 22 January 2003 that significant amounts of oil leaked from the *Tricolor* when a salvage tug accidentally damaged a temporary plug on one of the bunker tanks. A few days later, large numbers of heavily oiled seabirds started to wash ashore, first in France and Belgium and later also in The Netherlands.

Opening up the 'big bags': sorting and identification. Het openen van de 'grote zakken': sorteren en determineren. *(J.A. van Franeker)*

Between 29 January and 10 February 2003, large quantities of heavy bunker oil and numerous oiled seabirds washed ashore in The Netherlands. Standard beached bird surveys by the Dutch Seabird Group were promptly intensified to assess the damage and birds encountered by beach clean-up teams were collected and transported to laboratory facilities at the Royal Netherlands Institute for Sea Research on Texel for identification, counting and standard autopsies. This paper reports on the numbers of casualties found in The Netherlands, on species composition, and on characteristics (biometrics, sex ratio and age composition) of the most numerous seabirds affected by the spill. An attempt is made to identify the breeding areas where the stranded auks may have originated on the basis of their biometrics, and the results are compared with previous incidents as well as with material collected from chronic oil pollution in Southern North Sea (1982-2003; NZG/NSO unpubl. data).

METHODS

With daily strandings all over Zeeland and part of Zuid-Holland, daily beached bird surveys were attempted before clean-up teams could begin work and possibly remove corpses. Where clean-up teams were already deployed, local authorities arranged for corpses to be separated from the oil and bagged for subsequent analysis. Dedicated beached bird surveys were discontinued after 10 February 2003, when numbers of oiled casualties washing ashore were down to 'background' levels (< 1.0 km^{-1}). Two large sacks (1m^3 "big-bags") of material were transported to Texel for identification, counting and standard autopsies. A third sack was sorted and counted in Zeeland by Pim Wolf. The sacks transported to Texel were found to contain 929 corpses, 121 (13%) of which were birds that had died in the seabird rehabilitation centre "De Mikke" in Middelburg (Walcheren), the rest having been picked up from beaches. The corpses were sorted, identified, checked for rings and counted, while a subsample of heavily oiled, intact and rather fresh corpses was dissected and studied in more detail. Autopsies of Common Guillemots *Uria aalge* and Razorbills *Alca torda* included biometrics (bill length (feathers to tip and nostril to tip), bill depth (at base and gonys), head length, wing length (flattened, stretched), and body mass) where possible, examination of external age characteristics (plumage and/or beak development; Camphuysen 1995a), an assessment of the body condition at the time of death (scores of subcutaneous and deposited fat, condition of breast muscle; on a 4-point scale, from 0 = no reserves to 3 = excellent condition, very fat; *cf.* Van Franeker 1983), moult (*cf.* Ginn & Melville 1983), sex (gonadal inspection), age (presence and size of *bursa Fabricii*, gonadal development; *cf.* Stieda 1880, Van Franeker 1983, Jones 1985, Camphuysen 1987), and condition of major organs (lungs, liver, kidneys, guts; on a 4-point scale, from 0 = severely affected to 3 = good condition; *cf.* Van Franeker 1983). Many corpses were heavily oiled and as a result, relatively few could be measured.

Differences between means were tested with a *t*-test assuming a normal distribution. Oiling rates were expressed as percentages of total body covered in oil, ranging from 0% (unoiled) to 100% (completely covered in oil). A separate category was used, labelled as 200% oiled) for birds that could not be visually identified, but needed to be touched instead (corpse surrounded by a thick layer of oil, hiding external features). Only oiled birds were included in the autopsies, for the unoiled birds were not related to the *Tricolor* incident.

Results were compared with autopsy results from 463 Common Guillemots and 174 Razorbills stranded in The Netherlands in earlier winters (Dec-Mar; 1982-2003) as a result of chronic oil pollution, and more specifically with heavily oiled casualties collected during oil incidents in April-May 1985 along the mainland coast (47 Guillemots, 6 Razorbills; Camphuysen 1990), off Zeeland in December 1991 (38 Guillemots; Camphuysen 1995b), and in February 1992 at Texel (76 Guillemots, 11 Razorbills; Leopold & Camphuysen 1992), all originating from winter/spring staging areas in the Southern Bight.

RESULTS

Birds found dead The first birds arrived around 28 January 2003 on the Dutch coast, following periods of predominantly southwesterly (22-26 January) and later westerly – occasionally gale-force - winds (27-28 January; Royal Netherlands Meteorological Institute (KNMI), station Vlissingen). Most casualties washed ashore before 9 February and a 20-day period of predominantly easterly winds (9-28 February 2003 SE-NE; KNMI Vlissingen) prevented any subsequent mass-strandings. Numbers of corpses peaked at Walcheren (Zeeland) with nearly 60 casualties km^{-1} (Table 1), while densities at Goeree (Zuid-Holland; 25km further to the north) were an order of magnitude lower (6.1 km^{-1}). Common Guillemots, Razorbills and Black-legged Kittiwakes *Rissa tridactyla* predominated in the kill, together representing 91% of 3300 casualties recovered on the Dutch coast (Table 2). In addition to this, approximately 700 casualties were received in seabird rehabilitation centres. A total of 4000 stranded individuals is a conservative estimate of the total number of *Tricolor* casualties that washed ashore in The Netherlands.

Table 1. Densities of oiled dead birds found in Zeeland (Z) and Zuid-Holland (ZH), late January - early February 2003.
Tabel 1. Dichtheden van gevonden olievogels in Zeeland (Z) en Zuid-Holland (ZH), eind januari-begin februari 2003.

Area	Province	km	Oiled birds found	Density n km^{-1}
Zeeuws Vlaanderen	Z	14	436	31.1
Walcheren	Z	37	2211	59.8
Neeltje Jans	Z	3	68	22.7
Schouwen	Z	18	489	27.2
Goeree	ZH	16	98	6.1
		88	3302	37.5

Table 2. Species composition of oiled birds found dead following the Tricolor *spill in Zeeland and Zuid-Holland, late January - early February 2003.*
Tabel 2. Soortensamenstelling van de olieslachtoffers die na de Tricolor*-ramp in Zeeland en Zuid-Holland werden gevonden.*

Species	Oiled birds found	%
Common Guillemot *Uria aalge*	2081	63.0
Razorbill *Alca torda*	819	24.8
Black-legged Kittiwake *Rissa tridactyla*	101	3.1
Black Scoter *Melanitta nigra*	60	1.8
Common Eider *Somateria mollissima*	32	1.0
Atlantic Puffin *Fratercula arctica*	28	0.9
Red-throated Diver *Gavia stellata*	27	0.8
Northern Gannet *Morus bassanus*	27	0.8
Northern Fulmar *Fulmarus glacialis*	22	0.7
Herring Gull *Larus argentatus*	22	0.7
Great Crested Grebe *Podiceps cristatus*	18	0.6
Little Auk *Alle alle*	17	0.5
Common Guillemot / Razorbill *Uria aalge / Alca torda*	16	0.5
Eurasian Oystercatcher *Haematopus ostralegus*	14	0.4
Great Black-backed Gull *Larus marinus*	4	0.1
Other species	13	0.4
	3302	

Table 3. Sex ratio and age composition of Common Guillemots and Razorbills killed in the Tricolor *spill and found in The Netherlands late January - early February 2003.*
Tabel 3. Geslachtsverhouding en leeftijdssamenstelling van Zeekoeten en Alken die tijdens de Tricolor-*ramp zijn gestorven en eind januari-begin februari 2003 in Nederland werden gevonden.*

	Adult	Immature	First year	Total	Sex ratio
Common Guillemot					
Female	60	12	16	88	35%
Male	114	15	35	164	65%
Total[1]	335	27	78	440	
Age composition	76%	6%	18%		
Razorbill					
Female	44	11	5	60	38%
Male	79	14	7	99	62%
Total[1]	200	37	25	262	
Age composition	77%	16%	8%		

[1]including unsexed birds

Sex, age and condition A total of 598 Common Guillemots and 267 Razorbills were examined in more detail. Of birds that could be aged (*n* = 437 Guillemots, 262 Razorbills), over three quarters were mature in both species (Table 3) with a sex ratio significantly different from equal in Guillemots (65% males; G_{adj} 12.71, *P* <0.001; *n* = 246) as well as in Razorbills (62% males; G_{adj} 5.41, *P* <0.001; *n* = 158). Only nine Guillemots were unoiled (1.7%), while oiling was unclear in a further 36 cases (probably post-mortem oiling; hence, *n* = 562). The remainder was classified as slightly oiled (6.4%), heavily oiled (10.3%) or more or less completely covered with oil (81.7%). Among the last group were 333 casualties (59.2%) classified as 200% oiled. In Razorbills (*n* = 263 when possibly post-mortem oiled birds were omitted), 1.9% were unoiled, 1.5% slightly oiled, 9.3% heavily oiled, 87.3% more or less completely oiled (190 scored as 200%; 72.2%).

The physical condition at the time of death was good in a large number of stranded individuals in both species. Of 250 Common Guillemots, only 20.0% were classified as severely emaciated (score 0-3 on a scale ranging from 0-9), 30.4% as having at least some traces of fat (score 4-6), and 49.6% as fat or very fat (score 7-9). Of 163 Razorbills, 16.0% were classified as emaciated, 20.2%

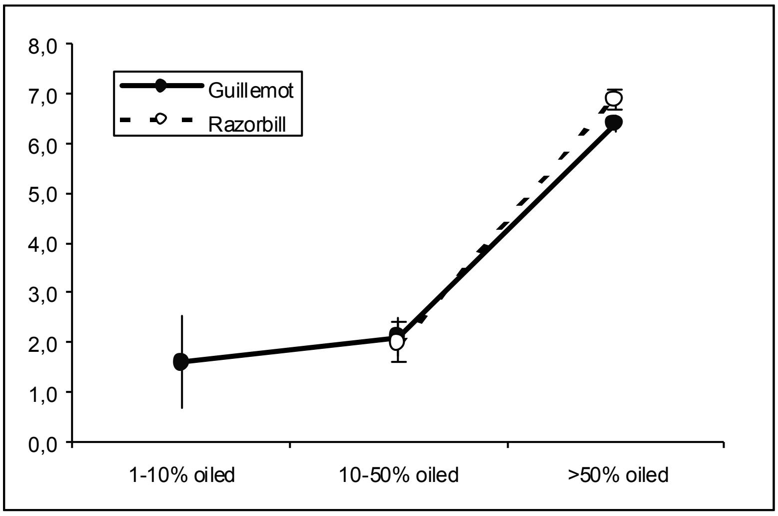

Figure 1. Body condition index and oil rate in Common Guillemots and Razorbills found dead (mean ± SE).
Figuur 1. Conditie-index en oliebevuilingspercentage van dood gevonden Zeekoeten en Alken (gemiddelde± SD).

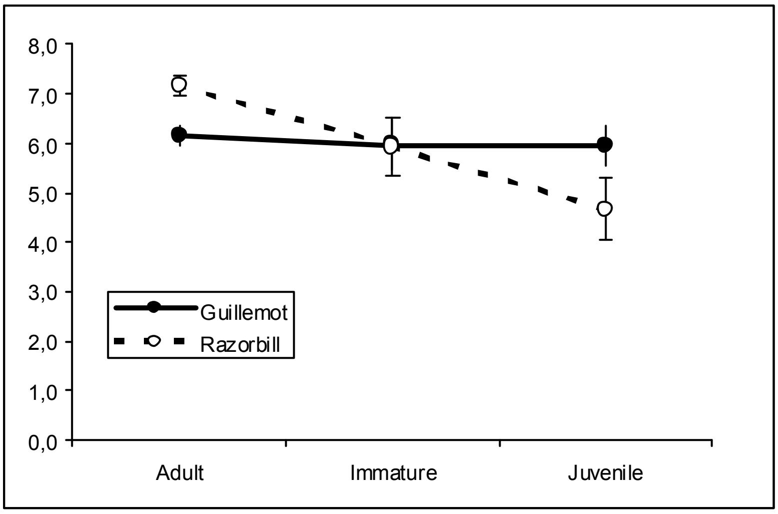

Figure 2. Body condition index and age in Common Guillemots and Razorbills found dead (mean ± SE).
Figuur 2. Conditie-index en leeftijd van dood gevonden Zeekoeten en Alken (gemiddelde ± SD).

Table 4. Biometrics of Common Guillemots killed in the Tricolor *spill and found in The Netherlands late January - early February 2003.*
Tabel 4. Biometrische gegevens van Zeekoeten die het slachtoffer waren van de Tricolor-*ramp en eind januari-begin februari 2003 in Nederland werden gevonden.*

	Bill tip-feathers	Bill nostril-tip	Bill depth at base	Bill depth at gonys	Wing length L	Wing length R
Adult female						
Sample	13	13	13	12	11	11
Mean±SE	46.6±0.7	40.2±0.6	13.9±0.2	12.5±0.2	203.0±1.4	203.0±1.4
Range	41.3-49.5	36.0-44.1	13.0-15.7	11.6-13.4	196-211	196-211
Immature female						
Sample	4	2	3	3	4	4
Mean±SE	47.8±2.6	38.5±1.0	14.2±0.4	13.5±0.0	205.0±2.4	204.5±2.7
Range	41.4-52.8	37.4-39.5	13.5-15.0	13.4-13.5	201-212	199-212
Juvenile female						
Sample	5	5	5	5	5	5
Mean±SE	44.6±0.96	36.9±1.1	11.8±0.46	10.6±0.51	192.4±2.8	192±2.8
Range	43.1-48.3	34.4-40.1	10.4-13.0	9.1-12.2	187-203	187-203
Adult male						
Sample	17	17	16	16	12	12
Mean±SE	49.1±0.5	42.2±0.5	14.8±0.4	13.1±0.2	204.8±1.9	204.6±1.8
Range	45.8-52.6	39.0-45.7	13.0-19.2	11.6-14.4	194-214	194-213
Immature male						
Sample	5	5	5	5	4	4
Mean±SE	47.9±0.9	41.2±0.9	14.1±0.7	12.6±0.6	202.7±2.6	202.7±2.6
Range	45.1-50.3	40.0-45.1	12.8-16.8	11.3-14.9	195-206	195-206
Juvenile male						
Sample	7	6	6	6	7	7
Mean±SE	46.3±1.0	40.2±0.9	13.1±0.3	11.8±0.2	195.9±1.3	195.9±1.3
Range	42.2-48.8	36.5-42.5	12.2-13.8	11.1-12.2	191200	191200

as in moderate condition, and 63.8% as being fat or very fat. In both species, a positive correlation was found between the condition index and the amount of oil on the birds: very heavily oiled individuals were usually in good condition when they died (Fig. 1). Because of the correlation between level of oiling and body condition, heavily oiled adult (96.8% of all examined adults) and juvenile Razorbills (91.7% of all juveniles) were compared separately. There was no change in the outcome, however, with a mean condition of 7.2 ± 0.2 in heavily oiled adults, as opposed to 4.9 ± 0.6 in heavily oiled juveniles. In Common

Table 5. Biometrics of Razorbills killed in the Tricolor *spill and found in The Netherlands late January - early February 2003*
Tabel 5. Biometrische gegevens van Alken die het slachtoffer waren van de Tricolor-*ramp en eind januari-begin februari in Nederland werden gevonden.*

	Bill tip-feathers	Bill nostril-tip	Bill depth at base	Bill depth at gonys	Wing length L	Wing length R
Adult female: bill W+ 1.5-2						
Sample	6	6	6	6	2	2
Mean±SE	30.3±1.1	20.9±0.4	16.8±0.4	19±0.6	203±1.0	203±1.0
Range	25.5-32.7	19.9-22.6	15.9-18.1	16.9-20.4	202-204	202-204
Juvenile female: bill 0+0						
Sample	2	2	2	2	2	1
Mean±SE	30.2±1.4	20.4±0.0	13.8±0.4	14.7±0.8	191±4.0	187
Range	28.8-31.5	20.3-20.4	13.4-14.1	13.9-15.4	187-195	
Adult male: bill W+ 1-2						
Sample	16	16	15	16	12	12
Mean±SE	32.9±0.3	21.6±0.3	17.7±0.4	19.9±0.2	194.8±0.6	194.6±0.6
Range	30.4-35.1	19.4-24.3	15.4-20.9	18.2-21.3	191-198	191-198
Immature male: bill W+0						
Sample	4	4	4	4	4	4
Mean±SE	30.4±0.7	20.3±0.4	15.3±0.3	17.4±0.3	193.3±1.0	193.3±1.0
Range	28.5-31.8	19.4-21.1	14.6-16.0	16.7-17.9	191-196	191-196
Juvenile male: bill 0+0						
Sample	2	2	2	2	2	2
Mean±SE	30.9±1.0	21.0±1.0	14.2±0.0	13.8±0.1	188.5±0.5	188.5±0.5
Range	29.9-31.9	20.0-22.0	14.2-14.2	13.7-13.8	188-189	188-189

Guillemots, condition indices were similar for adults (6.1 ± 0.2), immatures (6.0 ± 0.5), and juveniles (6.0 ± 0.4; Fig. 2). In Razorbills, however, condition indices were significantly higher in adults (7.2 ± 0.2) than in immatures (5.9 ± 0.6; t_{149} = 2.38, P< 0.02), and rather low in juveniles (4.7 ± 0.6), but not significantly different from immatures (t_{36} = 1.26, n.s.). Condition indices in adult Razorbills were significantly higher than in adult Common Guillemots (t_{294} = 3.56, P< 0.01), but similar in immatures and juveniles of either species (juvenile Razorbill versus Guillemot: t_{61} = 1.41, n.s.).

The condition of the lungs in the heavily oiled Common Guillemots (CI 0.9 ± 0.1, n = 229, on a scale ranging from 0-3) and Razorbills (1.0 ± 0.1, n = 156) was generally very poor compared to all other organs (gut, kidney and liver, range 2.5-2.9). It was observed that most of the casualties had inhaled oil

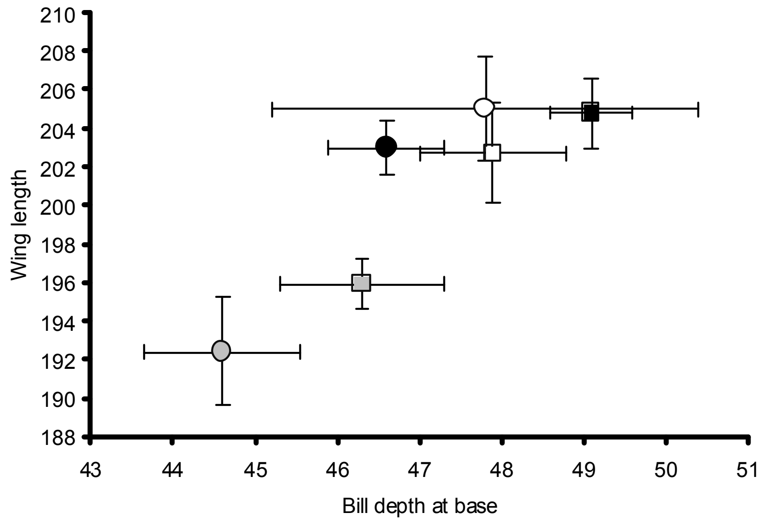

Figure 3. Bill length versus wing length (mean ± SE) in adult (black), immature (white) and juvenile (grey) male (squares) and female (circles) Common Guillemots. Sample size in Table 4.

Figuur 3. Snavellengte versus vleugellengte (gemiddelde ± SD) bij adulte (zwart), onvolwassen (wit) en juveniele (grijs) mannelijke (vierkant) en vrouwelijke (cirkel) Zeekoeten. Steekproefgrootte in tabel 4.

and as a result the lungs were shiny black. Rather low condition indices were found in moderately oiled Common Guillemots (1.8 ± 0.3, n = 9), but otherwise, the organs in slightly oiled, moderately oiled as well as heavily oiled auks ranged on average between 2.0 and 3.0 on the CI scale.

Biometrics The biometrics for Common Guillemots and Razorbills are tabulated in Tables 4 and 5. Wing length versus bill length (tip to feathers), two often-used biometrics to discriminate between Common Guillemot populations and age categories, are plotted in Fig. 3. In Common Guillemots, mean wing length was significantly different between adult and juvenile females (t_{14} = 3.52, P< 0.01), between immature and juvenile females (t_7 = 2.93, P< 0.01), between adult and juvenile males (t_{17} = 3.14, P< 0.01), and between immature and juvenile males (t_9 = 2.39, P< 0.05). Within age categories between the sexes, mean wing length was not statistically different. Mean bill length was significantly different between adult males and adult females (t_{26} = 2.80, P<

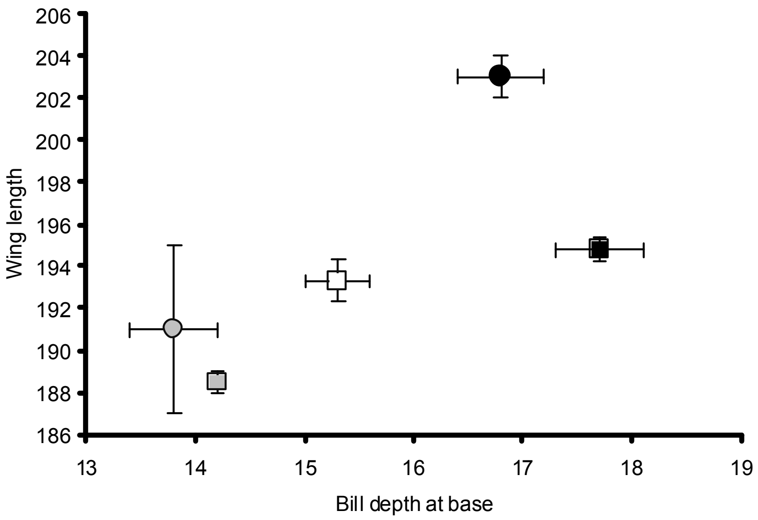

Figure 4. Bill depth at base versus wing length (mean ± SE) in adult (black), immature (white) and juvenile (grey) male (squares) and female (circles) Razorbills. Sample size in Table 5.

Figuur 4. Snavelhoogte aan de snavelbasis versus vleugellengte (gemiddelde ± SD) bij adulte (zwart), onvolwassen (wit) en juveniele (grijsy) mannelijke (vierkant) en vrouwelijke (cirkel) Alken. Steekproefgrootte in tabel 5.

0.01), between adult males and juvenile males (t_{22} = 2.78, $P<$ 0.05), but not between adult females and juvenile males (t_{18} = 0.24, n.s.), juvenile females and juvenile males (t_{10} = 1.08, n.s.), adult males and immature males (t_{18} = 1.07, n.s.), or immature males and juvenile males (t_{10} = 1.10, n.s.). In Razorbills, sample sizes were rather small in most sex/age categories. The two often-used biometrics to discriminate between Razorbill populations (wing length and bill depth at base) are plotted in Fig. 4. Mean bill depth was similar in adult males and adult females (t_{19} = 1.38, n.s.), but significantly different between adult males and immature males (t_{17} = 3.19, $P<$ 0.01). The wing length of only two suitable adult females was strikingly different from adult males, as well as from juvenile females (Fig. 4).

Table 6. Mean condition index (CI) ± SE of Common Guillemots and Razorbills killed in the Tricolor *spill, in three other spills in The Netherlands (December 1991, February 1992, April-May 1985), and due to chronic oil pollution (Dec-Mar 1982-2003).*

Tabel 6. Gemiddelde conditie-index (CI) ± SD van Zeekoeten en Alken die om zij gekomen bij de Tricolor*-ramp vergeleken met drie andere olierampen in Nederland (december 1991, februari 1992, april-mei 1985) en met sterfte als gevolg van chronische olieverontreiniging (dec-mrt 1982-2003).*

		Guillemot		**Razorbill**	
	Oiling	CI ± SE	*n*	CI ± SE	*n*
NSO chronic	Light-moderate	1.3 ± 0.1	444	1.1 ± 0.2	151
Spring 1985	Heavy	7.0 ± 0.2	47	7.2 ± 0.7	6
Texel 1992	Heavy	7.9 ± 0.1	76	8.0 ± 0.1	11
Zeeland 1991	Heavy	7.7 ± 0.3	38		
Tricolor	Heavy	6.1 ± 0.2	250	6.8 ± 0.2	163

DISCUSSION

Condition, age composition and sex ratio The condition index (CI) of both Common Guillemots (7.7 ± 0.3) and Razorbills (6.8 ± 0.2) was very high and this may be considered typical for oil incidents where birds get simply smothered in oil (Table 6). The presence of fat stores and breast muscles in good condition is believed to indicate instant death, as opposed to a prolonged trajectory of starvation and decline in lightly or moderately oiled casualties that try to stay clear of the coast for as long as they can. Most organs were in good condition, except the lungs in the heavily oiled casualties, as opposed to autopsy results in usually partly oiled birds that died from chronic oil pollution (gut infections in most casualties as well as pneumonia rather than lungs smothered in oil; NZG/NSO unpubl. data), generally confirming the observations based on the presence of reserve tissue and breast muscles: very healthy birds have been killed in the *Tricolor* spill and death was instant.

In Common Guillemots killed in the *Tricolor* incident, an extraordinary 76% were classified as adult birds (*n* = 437). This ratio was significantly different from the 1991 spill in Zeeland (21.1% adults, *n* = 38; G_{adj} = 45.3, df = 2, P< 0.001), from the Texel spill in 1992 (14.5% adults, *n* = 76; G_{adj} = 107.9, df = 2, P< 0.001), from winter birds killed by chronic oil pollution (47.2% adult, *n* = 462; G_{adj} = 91.5, df = 2, P< 0.001) and certainly from the spring 1985 incident, when adults are presumed to have returned to the colonies (6.5%

adults, $n = 46$; $G_{adj} = 88.7$, df = 2, $P < 0.001$). In Razorbills, where a similar 77% of the *Tricolor* casualties were found to be adults ($n = 262$), the age composition was not significantly different from Dutch winter birds killed by chronic oiling (72.3% adults; $G_{adj} = 1.85$, df = 2, n.s.). Small samples obtained in oil spills in spring 1985 (16.7% adults, $n = 6$) and winter 1992 (9.1% adults, $n = 11$) were rather different. These results indicate that, unlike most other strandings, a vital part of the wintering Common Guillemot population was affected: mature birds in excellent pre-breeding condition. It is interesting to note that in the *Prestige* oil spill, happing only a month earlier in NW Spain, 85% of the affected Common Guillemots were juveniles (*pers. obs.* CJC). For Razorbills, where also mainly adults in excellent condition were hit, these results may be less unusual. Since the number of Razorbills was larger than in most previous events, and while the population size of Razorbills is comparatively small, the *Tricolor* spill can be considered one of the more serious oil incidents in recent years affecting this species in the North Sea.

Both in Common Guillemots and in Razorbill, with sex ratios significantly different from equal, the samples were biased towards males and this was true for all age categories. The sex ratio in adult Guillemots from the *Tricolor* (65.5% males, $n = 174$) was significantly different from the large sample of adult winter birds killed by chronic oiling (54.8% males, $n = 210$; $G_{adj} = 4.58$, df= 1, $P < 0.01$) and the same was true for juveniles, which were slightly biased towards females in the material obtained from chronic oiling (*Tricolor* 68.6% males, $n = 51$; chronic oiling 46.7% males, $n = 135$; $G_{adj} = 7.24$, df= 1, $P < 0.01$). When the sex ratio of the *Tricolor* birds for each of the age categories was compared with material from any of the other spills, the differences were either not significant, or the samples were to small to warrant any testing. A bias towards males seems a general phenomenon in Dutch winter material. In adult Razorbills, the sex ratio of adult *Tricolor* casualties (64.2% males, $n = 123$) was significantly different from adult birds obtained as a result of chronic oiling in winter (49.1% males, $n = 112$; $G_{adj} = 5.45$, df= 1, $P < 0.01$). Samples of immatures and juveniles were generally too small to allow any sensible testing.

The biometrics of the Common Guillemots would point at the *U. a. aalge* subspecies (Cramp 1985). The wing length can be compared with the European cline in wing length drawn together by Peter Hope Jones (Jones 1984, 1988). A mean length of 203±1.4 mm as in adult females and 204.8±1.9 mm as in adult males would be consistent with Scottish breeding birds at approx. 57°N latitude. This suggestion is confirmed by an analysis of ringing recoveries based on *Tricolor* casualties (Grantham 2004), where the east coast of Scotland was identified as the area where ringed individuals mostly originated from. For Razorbills, the situation is more complex. The biometrics in Table 5 for adult males and immatures are consistent with measurements of the *islandica* subspecies anywhere in Britain, Ireland or Iceland (Cramp 1985); a more precise location cannot be pinpointed. Two adult females were remarkably long-winged, but with beak measurements that were consistent with the *islandica* subspecies. Grantham (*pers. comm.*) confirms the subspecies from ringing recoveries and indicates that the east coast of Scotland is again a likely breeding area from where many casualties may have originated.

Previous oil incidents Following a westerly storm in December 1991, hundreds of heavily oiled Common Guillemots washed ashore at Walcheren, originating probably from the same wintering grounds as the casualties found in The Netherlands following the *Tricolor* spill (Camphuysen 1995b). As indicated before, however, with only 21.1% adults in 1991, the age composition of the Guillemots found dead was strikingly different from that during the *Tricolor* spill. Similar in both kills were the excellent condition of the auks at the time of death (Table 6) and the severe oiling of the casualties ('200%').

Using back-calculations based on wind-drift models, Leopold & Camphuysen (1992) expected the wintering grounds of auks that were found on Texel in February 1992 to be situated in the central Southern Bight, about 110 km north of the *Tricolor* wreck site. Again, the age composition of the Guillemots found dead was significantly different from that during the *Tricolor* spill, with only 14.5% classified as mature birds in 1992. Condition at the time of death (Table 6) and the severe oiling were again similar.

Even further to the north, a spring staging area just north of the Brown Bank, was the calculated area where hundreds of heavily oiled Common Guillemots found dead in April-May 1985 along the mainland coast of Noord-Holland originated (Camphuysen 1990). A similar scenario (instant death due to heavy oiling; excellent condition at the time of death) was reported as during the *Tricolor* spill, but the incident took place when most adults had already returned to their breeding colonies: only 6.5% were recorded as mature birds.

These four spills are subsamples of what could have been the same wintering population, at slightly different times of the year. Three spills could not be attributed to a particular source (characteristic of chronic oil pollution), but the events were clear-cut in time and space and could therefore be isolated as particular incidents. The most striking difference between the three smaller incidents and the *Tricolor* spill is the age-composition in the affected Common Guillemots and the seemingly high proportion of mature birds in the latter. Routine beached bird surveys provide some insight in the age composition of stranded Common Guillemots, because juveniles can be separated with a high degree of certainty from immatures and adult birds on the basis of their underwing pattern (white tips on greater under wing coverts are characteristic for juvenile birds; Sandee 1983; Camphuysen 1995a). Summarising beached

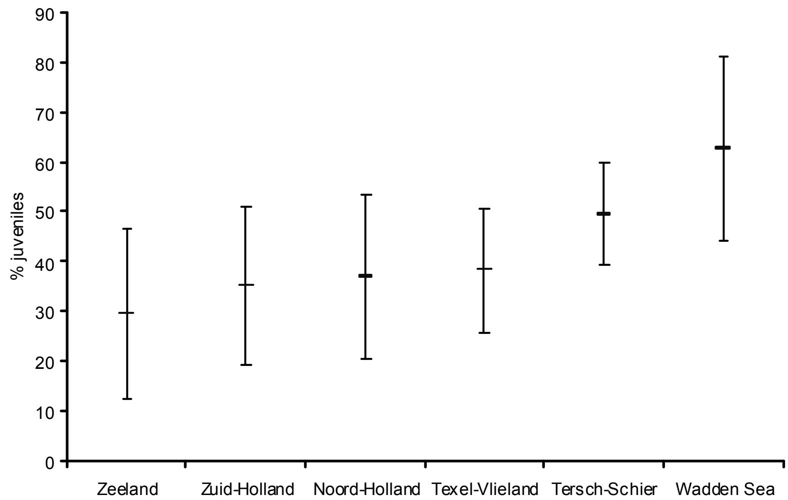

Figure 5. Mean proportion (± SD) of juvenile Common Guillemots based on white tips at greater under wing coverts during routine beached bird surveys in The Netherlands, 1980-2003 (cf Camphuysen 1995a) for each major subregion. Samples are based on at least 10 corpses each winter (Nov-Apr).

Figuur 5. Gemiddeld aandeel van juveniele Zeekoeten (witte toppen op ondervleugeldekveren) tijdens de reguliere stookolieslachtoffertellingen in Nederland, 1980-2003 (cf Camphuysen 1995a) per kustgedeelte. Steekproeven zijn gebaseerd op minimaal 10 kadavers per winter (nov-apr).

bird survey data collected between 1980 and 2003, using 7798 properly aged casualties found in winter (Nov-Apr), suggest a south → north increase in the proportion of juvenile birds (Fig. 5) and, more importantly, that a proportion as found in the *Tricolor* spill is by no means unusual (range 61.7 ± 12.4 % to 70.4 ± 17.0 % 'non-juveniles' in the four most southerly subregions). Grantham (2004) observed a similar pattern, where "birds recovered further north were more likely to be immatures, whereas birds recovered further south in the North Sea were more likely adults". With a general tendency of juvenile Common Guillemots to winter further to the south from their natal colonies than adults (Harris & Swann 2002), it should be realised that the adults and immatures recovered in a single spill might well originate from different breeding areas. With regard to the *Tricolor* spill, most (ringed) adults originated from the well-studied Scottish east coast, where ringing effort is rather high. The immatures and juveniles found during the incident, very few of which were ringed, might as well have originated form colonies further to the north, where ringing effort is considerably less. The biometrics obtained from these not fully grown individuals are unlikely to provide the evidence to support this, in the absence of back-ground data that can be used to discriminate between populations for young birds.

Numbers of birds With approximately 4000 birds found in The Netherlands, about 21% of the total number of casualties of the *Tricolor* spill recovered along the eastern seaboard of the English Channel crossed Dutch borders. Approximately 9200 casualties were found in Belgium (Velter & Rodts 2003; Stienen *et al.* 2004), another 5500 were recovered in Northern France (Jacques *et al.* 2003). Common Guillemots predominated in all countries (70% in France, 65% in Belgium, 63% in The Netherlands), with Razorbills ranking second in all areas (17% in France, 22% in Belgium, 25% in The Netherlands). Numbers of Great Crested Grebes were low in The Netherlands (0.6%) in comparison with numbers recovered in France (4.0%) and Belgium (3.3%). An estimated 20 000 individuals may have washed ashore, while unknown numbers may have gone lost at sea, particularly after 9 February.

Using daily weather reports (KNMI Vlissingen, mean wind direction and mean wind velocity; http://www.knmi.nl/voorl/weer/), assuming a corpse drift between 2 and 4% of the wind speed (Bibby & Lloyd 1977; Jones *et al.* 1978; Bibby 1981), vectors calculated from Westkapelle (Walcheren) would lead to the wreck site at 24 January 2003 (assuming max. corpse drift; Fig. 6). Alternatively, vectors would lead to the wreck site on 22 January 2003 when 3% of the wind speed is assumed. This exercise suggests that the birds most likely originated from an offshore area between Fairy Bank, North Falls, and Oost-Hinder, probably with additional casualties from Bligh Bank and Thornton Bank, but that the deadly slicks crossed more typical Great Crested Grebe habitat (coastal waters 10m deep or less) rather swiftly during stormy weather on 28 January. From the wind data, it seems unlikely that slicks and corpses travelled much further to the north than Schouwen (and indeed, densities at Goeree were an order of magnitude lower than those at Walcheren). In France (66%) and Belgium (54%) proportionally many more casualties were still alive when found ashore (only 19% of those recovered in The Netherlands), indicating active movements rather than passive, wind-influenced corpse drift.

Winds were very favourable for rapid strandings, so that relatively few birds may have disappeared unrecorded at sea, at least until 9 February 2003. However, with such thick oil, birds may sink or go unrecorded during clean-up operations at sea (mechanical clean-up) or on beaches. Therefore, estimates ranging from twice to at most five times the stranded numbers seem reasonable, suggesting a kill of between 40 000 and 100 000 seabirds, the majority of which

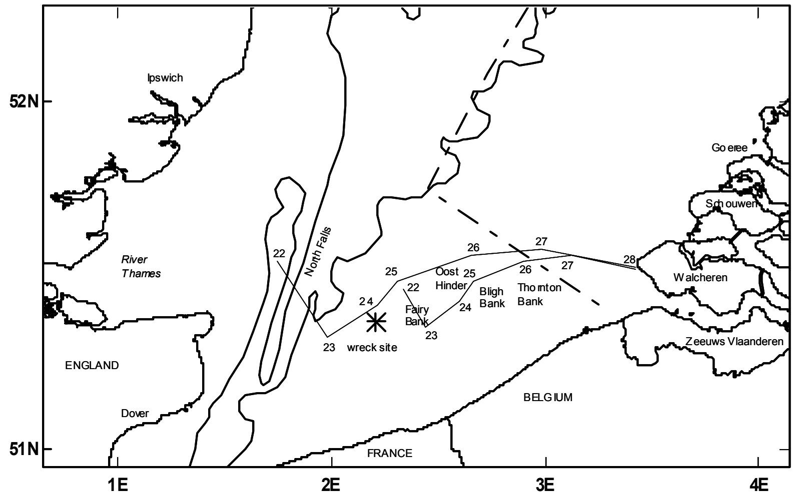

Figure 6. Wreck site of the Tricolor *and back calculations of floating corpses using daily wind data measured at Vlissingen (Walcheren) and assuming 4% of wind speed (far-ranging) and 3% of wind speed (southern leg) between 22 and 28 January 2003. Boundaries of the Dutch sector of the North Sea are indicated by a dashed line, 30m depth contours indicate the deeper water region of the central Channel area.*

Figuur 6. Ligging van de gezonken Tricolor *en de berekende positie van drijvende kadavers aan de hand van de dagelijkse windgegevens van meetpost Vlissingen (Walcheren). Hierbij is uitgegaan van 4 en 3% van de windsnelheid voor respectievelijk de verre en de minder verre route. De begrenzing van de Nederlandse sector van de Noordzee is aangegeven met een onderbroken lijn. De 30-meter dieptelijnen markeren het diepere water van de centrale kanaalzone.*

were Common Guillemots (25 000-62 500) and Razorbills (8000-20 000). The 20-day period of easterly wind in the rest of February may have sent corpses of birds to England and it is noteworthy that the late February 2003 beached bird survey in SE England had the highest oil rates since at least 1991 (68.8% oiled for all species combined, versus 19.8% in 2002; Royal Society for the Protection of Birds, unpubl. data).

That very large numbers of seabirds could have been killed in a mid-winter oil incident in the English Channel was foreseen. Carter *et al.* (1993) categorised the area where the *Tricolor* sank as of the highest vulnerability between December and March, mainly because of offshore concentrations of auks and nearshore concentrations of divers and seaduck. Offringa *et al.* (1996) and Seys *et al.* (2001) have highlighted the importance of the English Channel as a wintering area for seabirds in more recent years. The fact that a salvage operation, ultimately causing the *Tricolor* bunker tanks to leak oil, was not postponed until April was unfortunate, for that would have saved many thousands of seabirds from a miserable death. On the other hand, the repeated collisions of cargo vessels and tankers with the sunken wreck (plus a dozen or so near-hits reported from the area; Hans van Rooij, Smit Salvage *pers. comm.*) made the wreck a time-bomb that would explode anyway, possibly within the same time-frame, and possibly with even more oil spilled if for example a laden tanker struck the wreck and spilled it's own cargo. With the risk of greater disaster in mind, the untimely salvage operation could be defended. It is doubtful, however, if the responsible authorities fully appreciated the environmental risks taken with that decision and if they had a copy of the JNCC vulnerability atlas at hand (Carter *et al.* 1993).

The combination of data strongly points at the NW North Sea as a breeding area of both the Common Guillemots and the Razorbills affected by the *Tricolor* spill and the sheer number of casualties, as well as the very high proportion of mature birds, would lead to the expectation that an immediate effect on the breeding population has to be expected (extra adult winter mortality, lower returns into the colonies in the 2003 season). A follow-up project is required to assess the damage in the affected populations and it is a fortunate coincidence that the Isle of May, one of the best-studied auk colonies is situated in that area.

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HET *TRICOLOR* OLIE-INCIDENT: KARAKTERISTIEKEN VAN DE IN NEDERLAND AANGETROFFEN OLIESLACHTOFFERS

Tussen 28 januari en 9 februari 2003, spoelden ongeveer 4000 zwaar met olie besmeurde zeevogels aan op de Nederlandse kust: 21% van de ongeveer 20 000 olieslachtoffers die als gevolg van de olieramp met de *Tricolor* op de kust van Noord-Frankrijk, België en Nederland zijn gevonden. 91% van de gevonden vogels waren Zeekoeten, Alken en Drieteenmeeuwen. Ongeveer 600 Zeekoeten en 267 Alken werden aan een nadere inspectie onderworpen en een groot deel van deze dieren werd inwendig onderzocht. De dissecties wezen uit dat de alkachtigen in een uitstekende conditie verkeerden op het moment dat zij met de olie in aanraking kwamen; een indicatie voor een plotselinge dood als gevolg van verstikking in teer. Van 440 Zeekoeten waarvan de leeftijd kon worden bepaald was 76% adult en er waren meer mannetjes dan wijfjes getroffen (65% man). Van 262 Alken was 77% adult en ook hier overheersten mannetjes het monster (62%). Op grond van biometrische bepalingen wordt verondersteld dat de meeste Zeekoeten tot de subspecies *Uria aalge aalge* behoorden, terwijl de Alken werden geclassificeerd als *Alca torda islandica*. Op grond van de vleugellengte waren de Zeekoeten vermoedelijk van Schotse kolonies afkomstig (57°NB), een bevinding die door ringmeldingen werd ondersteund. De totale sterfte als gevolg van het lek in de *Tricolor* (2-5x het gevonden aantal vogels) bedroeg vermoedelijk ongeveer 40 000-100 000 zeevogels (25 000-62 500 Zeekoeten, 8000-20 000 Alken). Met een zodanig hoog percentage adulte vogels onder de getroffen alkachtigen, klaarblijkelijk kerngezonde broedvogels, mag een onmiddellijk effect op de getroffen populaties worden voorzien: een verminderde terugkeer van broedvogels in het seizoen 2003. Indien meer jonge vogels zouden zijn getroffen, dan zou zo'n effect worden uitgesteld over meerdere jaren en is er doorgaans weinig van te merken. Opgemerkt dient te worden dat het effect van de *Tricolor* aanzienlijk geringer zou zijn geweest indien de bergingsoperatie (waardoor het lek werd veroorzaakt) zou zijn uitgesteld tot de zomer. De kwetsbaarheid van het gebied is buitengewoon hoog, maar vooral in de winter (dec-mrt).

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THREE COLOURS OF BLACK: SEABIRD STRANDINGS IN BELGIUM DURING THE *TRICOLOR* INCIDENT

ERIC W.M. STIENEN[1], JAN HAELTERS[2], FRANCIS KERCHKHOF[2] & JEROEN VAN WAEYENBERGE[1,3]

Stienen E.W.M., Haelters, J., Kerckhof, F & van Waeyenberge, J. 2004. Seabird strandings in Belgium during the *Tricolor* incident. Atlantic Seabirds 6(3/S.I.): 129-146. *After a small amount of oil had leaked into the southern North Sea as a results of the collision between the oil tanker* Vicky *and the sunken car carrier* Tricolor *on 1 January 2003, 249 oiled birds (98% Guillemot* Uria aalge *and Razorbill* Alca torda*) were received at the Bird Rehabilitation Centre at Ostend, Belgium. Following a second larger oil spill during the salvage works of the* Tricolor *a few weeks later, in total 9,177 birds stranded at the Belgian coast during the period 23 January to 15 February. This time, virtually all birds were heavily oiled and more than half of the birds were still alive on arrival in Ostend. More than 90% of the victims were Guillemot and Razorbill; other species that accounted for more than 1% of the stranded birds were Great Crested Grebe* Podiceps cristatus *and Common Scoter* Melanitta nigra*. The birds stranded in three waves. A first peak in numbers (> 1,000 victims per day) occurred at 26 January and consisted of high proportions of Guillemots that managed to reach the coast alive despite unfavourable wind conditions. In the following weeks, the daily numbers of stranded birds were closely related to the prevailing wind conditions. The second and third peak in the number of strandings coincided with two periods of strong onshore winds. Changes in the species composition and the location where the birds were found are thought to reflect the movements of the oil slick perpendicular and parallel to the coastline, respectively. The proportion of Razorbills among the auks found during the incident greatly differed from that at sea and the proportion of dead birds was much higher among Razorbills than Guillemots. These differences can not be explained from differences in wintering areas. It is suggested that the third peak in strandings was at least partly related to a wreck among auks that was unrelated to the oil polluation.*

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INTRODUCTION

On 14 December 2002, the car carrier *Tricolor* collided with the *Kariba* and sank at about 35 km north of Dunkerque (Fig. 1). This was the first in a series of (near-) incidents in which the *Tricolor* was involved (see Kerckhof *et al.* 2004

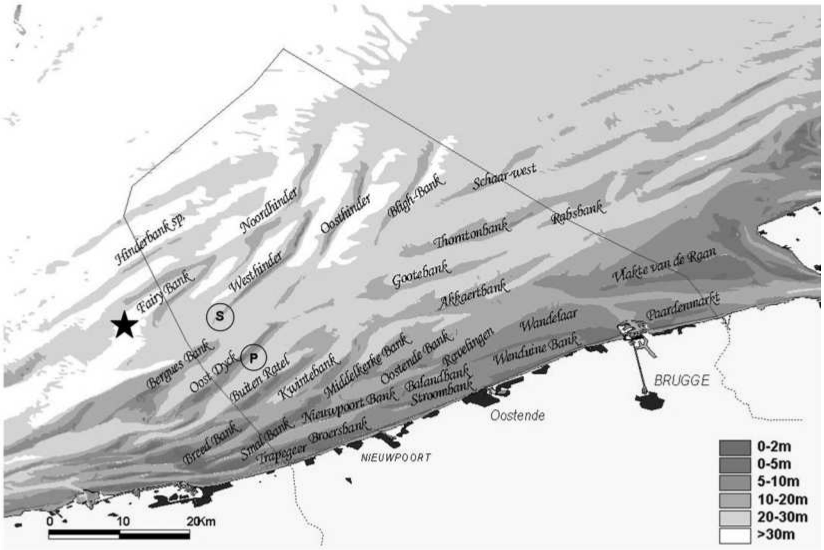


Figure 1. The Belgian marine waters and adjacent areas are characterised by various sand banks. Asteriks = position of the Tricolor, ***S*** *= weather station, P = position where the oil slick was encountered on 24 January. The coastline was divided into three sections: west coast = French border to Middelkerke inclusive, mid coast = Raversijde to Wenduine inclusive, east coast = Blankenberge to Dutch border.*

Figuur 1. De Belgische zeegebieden en de omringende wateren worden gekenmerkt door een aantal zandbanken op geringe afstand van de kust. Asteriks = positie van de Trciolor, ***S*** *= meteorologisch station, P = de plaats waar op 24 januari de olievlek is waargenomen. The kustlijn is opgedeeld in drie secties: westkust = Franse grens tot en met Middelkerke, middenkust = Raversijde tot en met Wenduine, oostkust = Blankenberge tot de Nederlandse grens.*

for a detailed chronological description of the incidents). A few days later, beached birds surveys were conducted along the Belgian beaches (16 December) as well as ship-based surveys in Belgian marine waters (16, 17 and 18 December). Obviously at that time no oil had leaked into the sea because both at sea and along the shoreline no conspicuous numbers of oiled birds were noted. The first oil was spilled on 1 January 2003 when the oil tanker *Vicky* came into collision with the wreck of the *Tricolor* and an unknown, but small amount of oil leaked into the sea. During beached bird surveys on 6-8 January, a total of 16 living oiled Guillemots *Uria aalge* as well as 23 (rather) fresh

Table 1. The number of victims received at the Bird Rehabilitation Centre in Ostend after the collision between the Vicky *and the* Tricolor *(*Vicky *1-22 Jan) and the numbers received at the ad hoc rehabilitation centre in Ostend after the major oil spill of the* Tricolor *(*Tricolor *23 Jan-15 Feb).*
Tabel 1. Het aantal slachtoffers dat werd binnengebracht in Vogelopvangcentrum te Oostende na de aanvaring tussen de Vicky *en de* Tricolor *(*Vicky *1-22 januari) en het aantal slachtoffers dat werd binnengebracht nadat een grotere olievlek was vrijgekomen tijdens de bergingswerkzaamheden aan de* Tricolor *(*Tricolor *23 januari-15 februari).*

Species	Vicky 1-22 Jan	Tricolor 23 Jan-15 Feb	Total
Guillemot *Uria aalge*	231	5875	6106
Razorbill *Alca torda*	12	2094	2106
Guillemot/Razorbill	0	411	411
Great Crested Grebe *Podiceps cristatus*	3	310	313
Common Scoter *Melanitta nigra*	0	125	125
Red-throated Diver *Gavia stellata*	0	63	63
Little Auk *Alle alle*	0	61	61
Kittiwake *Rissa tridactyla*	0	61	61
Larus spp.	0	35	35
Gannet *Morus bassanus*	1	33	34
Other	2	36	38
Atlantic Puffin *Fratercula arctica*	0	27	27
Kittiwake *Rissa tridactyla*	0	24	24
Velvet Scoter *Melanitta fusca*	0	22	22
Total	249	9177	9426

corpses of auks were found on 51.6 km Belgian beach. Although the densities of dead auks were similar to those in the 1990s (in both cases 1.2 auks km^{-1}), the oil rate of the corpses (78% of the corpses was oiled) was somewhat higher than oil rates in the 1990s (Seys *et al*. 2002b). From 1-22 January, 249 oiled seabirds were brought to the Bird Rehabilitation Centre in Ostend, of which respectively 92.8% and 4.8% were Guillemots and Razorbills *Alca torda* (Table 1).

A second larger oil spill occurred during the salvage operation of the *Tricolor* on 22 January. Again a relatively small quantity of oil was spilled (at most 170 tons), but this time it had disastrous effects on the seabirds wintering in the southern North Sea. We report here on the marine bird population at risk, the presumed movement of the oil patch as well as the number and species composition of birds collected along the Belgian coastline in the period following this oil spill. A detailed species list is given by Kerckhof *et al.* (2004).

METHODS

Study area The Belgian shoreline is only 66 km long. It mainly consists of easily accessible sandy beaches and more than half is built up with boulevards and buildings. The Belgian marine waters are shallow and dominated by strong currents, a high turbidity and four groups of linear sand ridges that extend beyond the French and Dutch border (Fig. 1). The sandbanks contribute to strong variations in water depth and sediment composition. Carter *et al.* (1992) designated the southern North Sea to be highly vulnerable to surface pollutants. The area is one of the most heavily navigated areas in the world (Maes *et al.* 2000) and hosts important numbers of seabirds (Offringa *et al.* 1996, Seys *et al.* 2001, Stienen & Kuijken 2003). A dense network of important shipping routes makes it very susceptible for ship collisions and oil pollution. It is one of the most polluted areas in the North Sea (Skov *et al.* 1996, Camphuysen 2004). It is for these reasons that oil pollution in the Belgian marine waters is regularly monitored from the air (Jacques et. al. 1991, Di Marcantonio 1999). Belgium has a long history in beached bird surveys (first census in 1962) and an extensive dataset on this is kept at the Institute of Nature Conservation. Recent publications describe patterns and trends in the numbers of beached birds and the proportions that are oiled, and give a more extensive description of the study area (Seys *et al.* 2002a, b).

For this study the Belgian shoreline was subdivided into three sections being the French border to Middelkerke inclusive, Raversijde to Wenduine inclusive and Blankenberge to the Dutch border (Fig 1). For convenience these section are called west coast, mid coast and east coast, respectively.

From 23 January to 15 February 2003, dead and living birds were retrieved from the Belgian shoreline by volunteers, civil servants and co-workers of Belgian rehabilitation centres and brought to an ad hoc rehabilitation centre at Ostend. Here birds were identified and counted. Virtually all birds were oiled and most were heavily oiled. In total 411 birds were only identified as “Razormots” because unpacking them from the thick layer of oil would have been too time consuming. During the first three days (23-25 January), the counting of birds was not yet organised and consequently daily numbers are not known. However, the casualties (living and dead) found during this period were kept at the rehabilitation centre and were counted altogether in the early morning of 26 January.

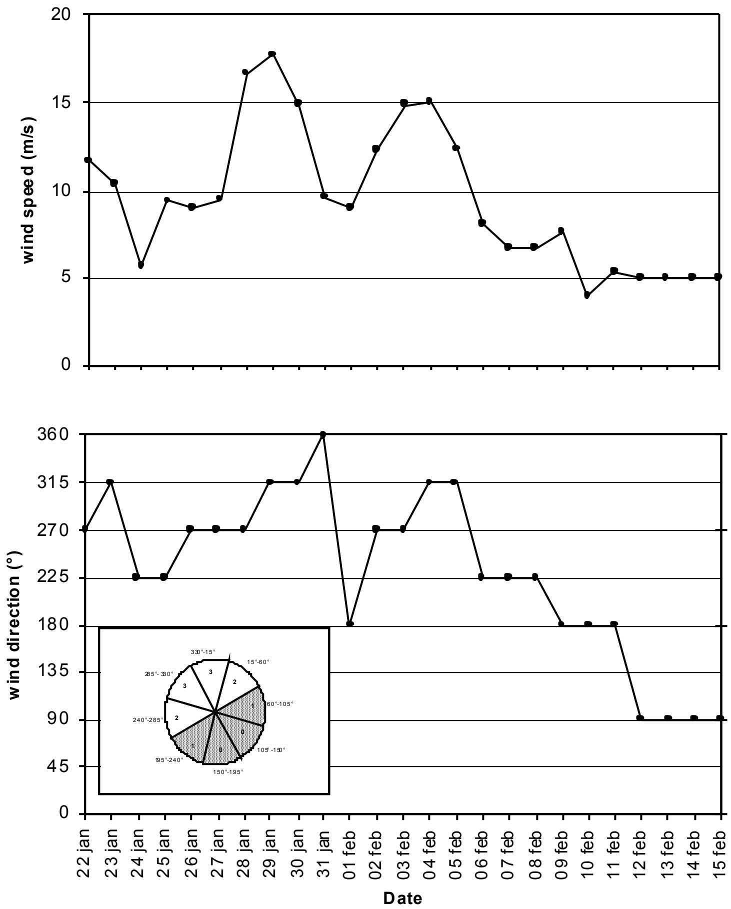


Figure 2. The average daily wind speed (upper graph) and the rounded mode of wind direction (lower graph) measured at the offshore meetstation Westhinder during the period 22 January – 15 February 2003. The inset in the lower graph shows the weighing factor (0-3) for each sector of 45° used to calculate the wind factor (see methods for further details). The inset shows the Belgian coastline that runs approximately from 240° to 60°.

Figuur 2. De gemiddelde windsnelheid (boven) en de modus van de windrichting (onder) gemeten op het offshore meetstation Westhinder tijdens de periode 22 januari – 15 februari 2003. De inzet toont de wegingsfactor (0-3) per sector van 45° die is gebruikt om de windfactor te berekenen (zie tekst voor details). In de inzet is de Belgische kustlijn te zien die loopt van 240°-60°.

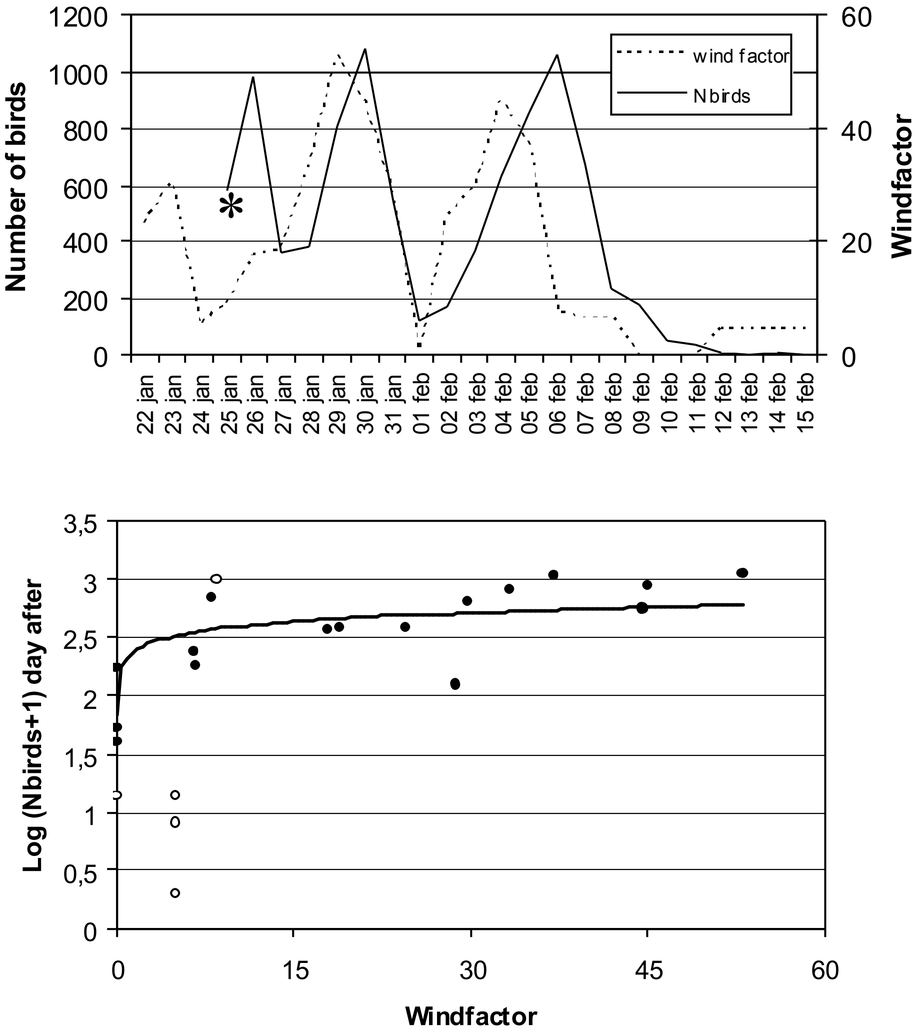


Figure 3. See opposite page for legend.
Figuur 3, Zie tegenoverliggende pagina voor bijschrift.

*Opposite page: Figure 3. During the period 27 January –11 February, but not before, fluctuations in the daily number of birds stranded along the Belgian coast largely resulted from differences in wind condition (upper graph). The lower graph shows that there was a strong positive relationship between the wind factor and the number of victims counted one day later (*log *[Nbirds + 1] = 0,111 ** ln *[wind factor] +2.333,* R^2 *= 0.64,* n *= 16). Circles represent omitted data from the period 23–26 January when almost exclusively living birds came ashore and data after 11 February when numbers were too low for a proper analysis. Birds brought in during the period 23-25 January were counted altogether afterwards and plotted here at 25 January (*).*

*Tegenoverliggende pagina: Figuur 3. In de eerste dagen (23–26 januari) was er geen duidelijk verband tussen de weersomstandigheden en het dagelijkse aantal vogels dat in het vogelopvangcentrum te Oostende werd binnengebracht, maar daarna zijn de schommelingen in de aantallen grotendeels te verklaren uit verschillen in windrichting en –snelheid, hier weergegeven als windfactor (figuur boven). De onderste figuur laat zien dat er een sterk positief verband is tussen de windfactor en het aantal slachtoffers dat één dag later werd geteld (*log *[aantal vogels + 1] = 0,111 ** ln *[windfactor] +2.333,* R^2 *= 0.64,* n *= 16). De open cirkels hebben betrekking op niet gebruikte gegevens uit de periode 23–26 januari toen vrijwel uitsluitend levende vogels aanspoelden en strandingen na 11 februari die vanwege het geringe aantal slachtoffers die niet werden gebruikt voor de analyse. Vogels die in de periode 23-25 januari werden binnengebracht, zijn allemaal tegelijk geteld en ingetekend op 25 januari (*).*

Weather conditions Wind speed (in $m.s^{-1}$) and direction (in degrees) were measured at sea every 10 minutes by the "Administratie Waterwegen en Kust" at the Westhinder station (51° 24' N, 2° 26' E) using international standards (Fig. 2). The wind direction was subdivided into eight categories of 45°, so that we could distinguish between offshore and onshore wind (Fig. 2). The daily mode of the wind direction was calculated and valued in a way that onshore winds were more important than offshore winds for beaching (Fig. 2). The daily wind factor was obtained by multiplying the average daily wind speed with this value.

Surveys at sea Ship-based surveys in Belgian marine waters have been carried out using standardised methods for counting seabirds at sea (Tasker *et al*. 1984, Komdeur *et al*. 1992). To calculate seabird densities, the numbers were corrected for birds missed at greater perpendicular distance. For transect counts that covered more than 1 km, seabird densities ($N.km^{-2}$) were calculated. Seabird densities were averaged for each rectangle of 1' x 1' (cf. Fig. 6). In this study we present averaged values for the period 1992-2003 as well as separate data from the winter 2002/03 (i.e. December-February).

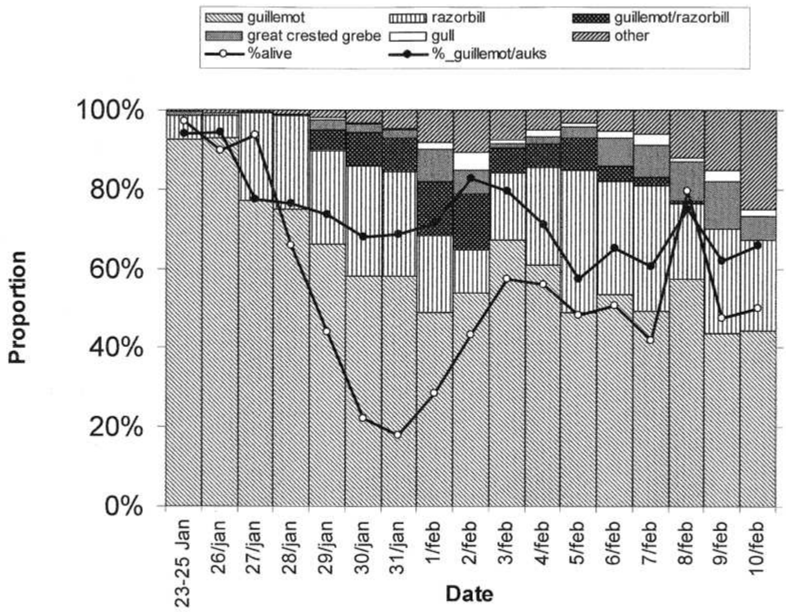


Figure 4. The variation in species composition of the birds stranded along the Belgian coast (bars) from 23 January – 10 February (after 10 February, sample sizes were too low to calculate proportions). The sample size is given in figure 2. The drawn lines represent the proportion of birds that were still alive when brought into the rehabilitation centre (white dots) and the proportion Guillemots among the Guillemots and Razorbills (black dots).

Figuur 4. Dagelijkse verschillen in de soortsamenstelling van de slachtoffers die langs de Belgische kust werden gevonden (balken) van 23 januari tot 11 februari (na 10 februari waren de aantallen te laag voor analyse). Het aantal vogels is weergegeven in figuur 2. De getrokken lijnen tonen het aandeel vogels dat nog in leven was bij binnenkomst in het vogelopvangcentrum (witte stippen) en het aandeel Zeekoeten in de groep Zeekoeten + Alken (zwarte stippen).

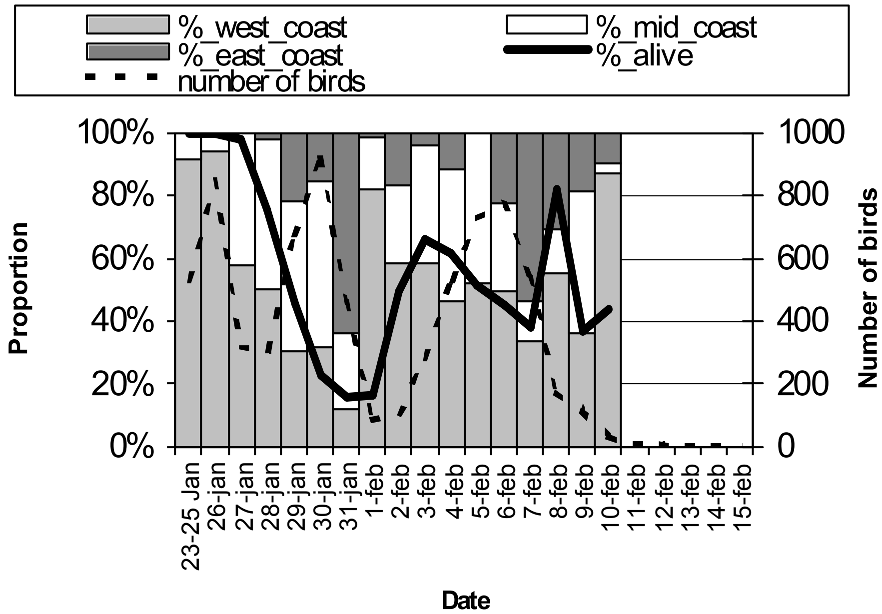


Figure 5. The relative number of Guillemots and Razorbills that beached at different sections of the Belgian coast (see Fig. 1 for divisions). The few auks found just over the French border and at sea were excluded from the analysis. After 10 February, sample sizes were too low (< 10 birds) to calculate proportions. The dotted line shows the number of birds processed and is plotted against the right axis.

Figuur 5. Het aantal Zeekoeten en Alken dat verhoudingsgewijs aanspoelde op verschillende segmenten van de Belgische kust (zie Fig. 1 voor de onderverdeling). De weinige alkachtigen die net over de Franse grens of op zee werden gevonden, zijn niet gebruikt voor de analyse. Na 10 februari waren de aantallen te laag (< 10 vogels) voor analyse. De onderbroken lijn (rechter as) geeft het aantal vogels dat is gebruikt voor de berekening.

RESULTS

From 23 January to 15 February 2003, 9,177 birds of 32 species were brought into the rehabilitation centre (Table 1). During this period three peaks can be distinguished when more then 1,000 birds day^{-1} stranded at the Belgian coast (Fig. 3). A first massive stranding occurred on 26 January and concerned almost exclusively Guillemots (92.5%) and Razorbills (6.1%). A remarkably high proportion of the birds found on this day (89.8%) were still alive on arrival at the rehabilitation centre (Fig. 4). A second peak in strandings took place from 29 to 31 January. Again the victims were mainly auks (94.2%), but by then the proportion of living birds had dropped to 28.4% and the proportion of Guillemots had dropped to 64.0%. After a few days with relatively low numbers of stranded birds, numbers increased again from 3 February onwards to a third peak on 6 February. During this peak relatively high proportions (14.1%) of species other than Guillemot and Razorbill were found (mainly Great Crested Grebes *Podiceps cristatus* and gulls) and the proportion of living birds amounted to 50.6%.

Except during the period 23 to 26 January, daily numbers of stranded birds were strongly related to the prevailing wind conditions 1 to 2 days earlier (Fig. 3). The second and third peaks in strandings both followed a period with strong onshore winds. During the first 4 days following the oil spill, the prevailing wind direction was offshore. Still high numbers of birds came ashore, but these were mainly live ones, reaching the coast on their own account.

During the first few days following the oil spill, the prevailing northwesterly winds pushed the oil over the Belgian border and slowly towards land. In the morning of 24 January we encountered a large oil patch at about 22 km from the coastline near the sandbanks Buiten Ratel and Oostdyck (Fig. 1). The oil slick stretched for several km in northwestward direction. Moderate west to southwest winds during the period 25 to 27 January, allowed for a further spreading of the oil over the Flemish Banks and the northern parts of the coastal banks. The areas first hit by the oil normally hold high densities of wintering auks (compare Fig. 6). Ship-based surveys taken in December 2002 and January 2003 suggested no strong deviations from this pattern. From 23-28 January, proportionately high numbers of auks (> 98% of all stranded birds) beached at the Belgian coast. At first birds stranded mainly at the Belgian west coast, but the oil appears to have drifted in easterly direction because soon also along the Belgian mid coast relatively high numbers of victims were found (Fig. 5). Strong north-northwest winds on 28 to 30 January, blew the oil further towards the coast and the oil hit the coastal region around the mid and east coast. This resulted in an increasing proportion of more inshore species like Great Crested Grebes (Fig. 4) and a decreasing proportion of birds found along the west coast (Fig. 5). During the next few days, the oil slick was subject to more easterly moderate winds (31 January to 2 February) that finally turned into an offshore direction. As a result, increased numbers of victims were found along the west coast on 1 February (Fig. 5), whereas the proportion of auks increased during the following few days (2 to 5 February; Fig. 4). From 3 to 7 February, strong northwesterly winds blew the oil patch onshore at the east

Table 2. The species composition (in %) of victims found along the Belgian coast during the Tricolor *incident compared with the at sea composition in Belgian marine waters in the winter 2002/03 (BCS_02/03) and the averaged at sea composition from the winters 1992-2002 (BCS_winter, published by Stienen et al. 2002). BCS_swimming = composition of predominantly swimming species in Belgian marine waters in an average winter. * = a relatively large group of Wigeons* Anas penelope *was counted in December 2002.*

Tabel 2. Het soortenspectrum van zeevogels (in %) gevonden tijdens de ramp met de Tricolor *in vergelijking tot de samenstelling in Belgisch mariene wateren tijdens de winter 2002/03 (BCS_02/03) en die in een gemiddelde winter (BCS_winter = gemiddelde waarden van scheepstellingen uitgevoerd in de periode 1992-2002 zoals gepubliceerd door Stienen et al. 2002). BCS_swimming = samenstelling van de zwemmende soorten in het Belgische zeegebied tijdens een gemiddelde winter. * = een relatief grote groep Smienten* Anas penelope *werd geteld in december 2002.*

	Tricolor	BCS_02/03	BCS_winter	BCS_swimming
Guillemot/Auk	91,3	33	35,3	71,1
Great Crested Grebe	3,4	5,7	3,8	7,7
Gavia spp.	0,7	1,9	2,2	4,4
Scoter	1,6	0,5	8,3	16,7
Kittiwake	0,7	10,2	10,4	
Larus spp.	0,4	33,4	36,9	
Gannet	0,3	7,2	1,7	
Fulmar	0,3	1,1	1,2	
other	1,3	7,1*	0,1	

coast. The relative numbers gradually increased along the east coast, while the relative number of Great Crested Grebe as well as other non-auks increased again after 5 February.

The species composition of the victims found along the beach greatly differed from the composition of the population at risk (Table 2). Compared to the situation at sea proportionally fewer gulls and more auks were found during the *Tricolor* incident. Although hundreds of gulls were seen with oiled plumage along the Belgian shoreline, only few were found dead. Generally, the stained gulls were much less heavily oiled than the auks and could not be caught by hand. During the following breeding season, many oiled gulls (both Herring *Larus argentatus* and Lesser Black-backed Gulls *L. fuscus*) were seen breeding in the colony at Zeebrugge (Belgium), but nothing is known about their reproductive success. The species composition of birds found during the *Tricolor* spill resembles more the average composition of swimming seabirds wintering in Belgian marine waters (Table 2). Only the proportions of beached Common Scoters *Melanitta nigra*, Great Crested Grebes and Red-throated Divers *Gavia stellata* were lower than expected from the surveys performed at sea. Ship-based surveys (Table 2) and aerial surveys of seaducks confirm that the number of scoters was relatively low during the winter 2002/03 (1049 individuals were counted from the air on 13 January 2003). On the other hand ship-based surveys suggest that relatively high numbers of Great Crested Grebes were present in the area at that time (Table 2). This is, however, not reflected in the number of stranded grebes.

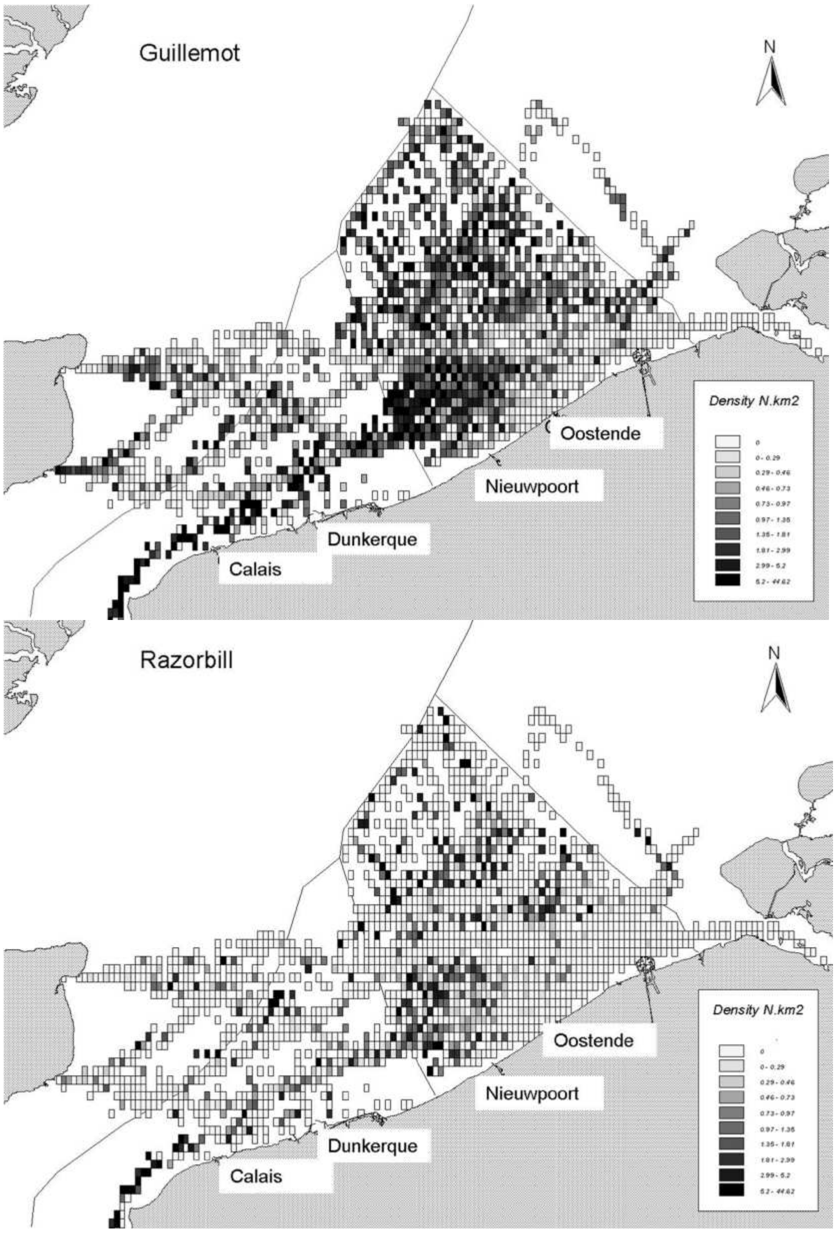
DISCUSSION

Typically, the *Tricolor* oil spill mainly affected birds that spend most time swimming on the water, whereas the more aerial gulls were less affected. Also during other major incidents, swimming birds were more sensitive to the oil pollution than gulls (e.g. Hope Jones *et al.* 1970, Harrison 1993, Piatt *et al.* 1990, Carter et. al. 1992). Many gulls spend the night on land making them even less sensitive to oil pollution. It was fortunate that relatively few scoters were present in the area this winter. During some winters, the Belgian marine waters hold more than 10, 000 Common Scoters, but numbers fluctuate heavily (Van Waeyenberge *et al.* 2001). It remains unclear why the numbers of stranded grebes and divers were relatively low, while ship-based surveys suggest proportionately higher numbers at sea at that moment. Behavioural differences as well as differences in the distribution of species might play a role in this.

Around 26 January 2003, peak numbers of seabirds stranded along the southwest coast of Belgium in spite of unfavourable wind conditions for beaching. This mismatch between wind and the number of stranded birds, in combination with the fact that the first victims were almost exclusively living birds strongly implies that many auks actively swam to the shoreline after being hit by the oil. At first, we found low numbers of Razorbills and high proportions of Guillemots among the victims. Only after the first peak, the relative numbers of Razorbill increased while at the same time the proportion of dead birds sharply increased (Fig. 4). In total 5,875 Guillemots were brought into the rehabilitation centre of which 36.5% were dead, whereas 62.5% of the 2,094 Razorbills were dead on arrival at Ostend. A possible explanation for this difference might be that Razorbills winter further offshore than Guillemots, making it less likely for them to reach the shore alive. In fact, other inshore species show similarly "low" proportions of dead birds as Guillemots (the proportion of dead birds among the received Great Crested Grebe, Red-throated Diver and Common Scoter was respectively 13.2%, 36.5% and 48.8%). In contrast, 70.5% of the more offshore living Kittiwakes had died on the arrival at rehabilitation centre. Ship-based surveys performed in the southern North Sea during the past 11 years, show that the core areas of both Razorbills and Guillemots are found directly above shallow sandbanks (Fig. 6). There are no obvious differences in the distribution of the two species, except for the Vlakte van de Raan that holds relatively low numbers of Razorbills. Surveys performed during the winter 2002/03 suggest a normal distribution pattern during this winter, except that the Vlakte Raan held rather low numbers of both species. Thus the relatively high numbers of dead Razorbills compared to that of Guillemots were probably not caused by a difference in the distribution between the two species. An explanation can, however, be found when examining the proportion of dead birds in relation to the finding date (Fig. 7). Both in Razorbill and Guillemot high proportions of living birds were found until 28 January, followed by a strong decrease until 1 February. During the first week of February, however, the two species greatly differed in the relative number of dead birds. In particular the period 4 to 7 February appears to be of interest. At that time high numbers of Razorbills (754 in total) stranded at the Belgian beach while the proportion of Guillemots was low (compare Fig. 4). At sea, Razorbills on average constitute only 13.3% of the auks in the study area (ship-based surveys during the period 1992-2002), while in the *Tricolor* strandings it amounted on average 26.3% and reached a maximum of 42.6% on 5 February. At sea a similar increase in the proportion of Razorbills was noted. Razorbills amounted to 4.3% and 2.9% of the auks at sea in December 2002 and January 2003, respectively. During the February surveys this proportion had increased to 17.6%. This increase seems not sufficient to explain the strong increase in the proportion of Razorbills found in the stranded birds.

From 4-7 February 2003, relatively high numbers of Little Auks *Alle alle* and Atlantic Puffins *Fratercula arctica* washed ashore the Belgian coast. Dissection of 33 Little Auks and 8 Atlantic Puffins revealed that the birds were severely emaciated and that the oil contamination had occurred post-mortem. The exceptionally high numbers and the post-mortem data strongly indicate that the birds were not killed by the oil, but starved to death because of food-shortage. Camphuysen (2003) describes a similar wreck at the same time among Atlantic Puffins and Little Auks in The Netherlands. Although found during the *Tricolor* incident the birds were emaciated and unoiled. Camphuysen (2003) suggests a mass displacement of weakened auks to the southern North Sea as a result of food shortage in the more northern parts of the North Sea. The timing of this wreck perfectly matches the third peak in seabird strandings along the Belgian coast, suggesting that it not only involved Atlantic Puffins and Little Auks, but also Razorbills.

Although other explanations (e.g. damage to the food stocks by the oil) can not be excluded, it thus seems likely that the third peak in strandings is at


Guillemot
N
Oostende
Nieuwpoort
Dunkerque
Calais
Density N.km2
0
0 - 0.29
0.29 - 0.46
0.46 - 0.73
0.73 - 0.97
0.97 - 1.35
1.35 - 1.81
1.81 - 2.99
2.99 - 5.2
5.2 - 44.62
Razorbill
N
Oostende
Nieuwpoort
Dunkerque
Calais
Density N.km2
0
0 - 0.29
0.29 - 0.46
0.46 - 0.73
0.73 - 0.97
0.97 - 1.35
1.35 - 1.81
1.81 - 2.99
2.99 - 5.2
5.2 - 44.62

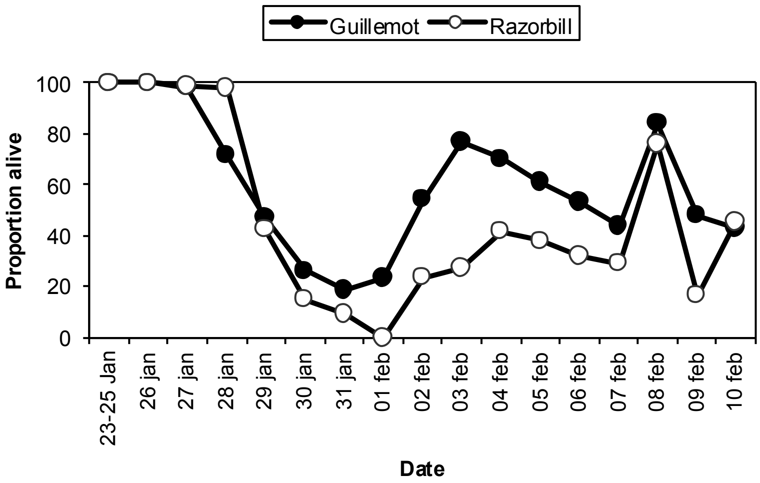


Figure 7. The daily proportion of Guillemot and Razorbill that were received alive at the rehabilitation centre in Ostend during the Tricolor incident.
Figuur 7. Het dagelijkse percentage Zeekoeten en Alken dat levend werd binnengebracht in het vogelopvangcentrum te Oostende tijdens het incident.

least partly caused by a starvation of auks that was unrelated to the *Tricolor* incident. This implies that the number of casualties from the *Tricolor* incident reported here as being oil victims might be somewhat exaggerated. On the other hand it is obvious that many *Tricolor* victims were not counted because they were left on the beaches, thrown away in dustbins or removed from the beach together with a thick layer of oil. Some oiled birds might never have reached the coastline because they sank to the bottom of the sea or drifted elsewhere. Beached Bird Surveys in the United Kingdom indicate that at least some birds drifted/swam in unexpected directions. In the south-east part of the UK,

Opposite page: Figure 6. The distribution of Guillemot (upper map) and Razorbill (lower map) in the southern North Sea during winter (period December-February) based on surveys at sea during the period 1992-2003.
Tegenoverliggende pagina: Figuur 6. De verspreiding van Zeekoet (figuur boven) en Alk (figuur onder) in de zuidelijke Noordzee tijdens de winter (december-januari) gebaseerd op scheepstellingen in de periode 1992-2003.

hundreds of oiled auks were found during the surveys in February 2003. This resulted in the highest oiling rates in that area since 1991 (Schmitt 2003). In literature, the number of birds that die but never come ashore greatly varies, from 0-100% (review in Seys *et al.* 2001). It is therefore not advisable to apply a correction for birds that were not recovered during the *Tricolor* incident in order to calculate the true number of victims. Drift experiments, including some performed in the southern North Sea, show that for a dead bird the probability to wash ashore depends for an important part on the wind (e.g. Hope Jones *et al.* 1970, Bibby & Lloyd 1977, Stowe 1982, Keijl & Camphuysen 1992 and review in Seys et. al. 2001). Also this study shows a strong relationship between wind direction and velocity on the one hand and the number of beached birds on the other. In fact during the *Tricolor* incident many factors were favourable for a high probability of recovery (wind conditions, distance to the shore as well as the effort put in searching the beaches).

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It would carry too far to personally thank the numerous volunteers, civil servants, co-workers of (local) governmental and non-governmental institutes and various non-profit organisations that in any way made this study possible. Our gratitude goes to all of them who helped picking up birds from the Belgian shore, transporting them to Ostend or otherwise supported this study. In particular, we would like to thank Walter Wackenier and Jeremy Demey for their tremendous effort. Various co-workers of the Institute of Nature Conservation and the Management Unit of the North Sea Mathematical Models assisted in the counting and identification of birds. Claude Velter kindly provided the number of victims received at the Bird Rehabilitation Centre Ostend after the *Vicky* hit the *Tricolor*. We further thank the volunteers that participated in the various ad hoc organised surveys in the weeks between the sinking of the *Tricolor* and the major oil spill. Many volunteers and personnel of the Institute of Nature Conservation participated in the surveys at sea. We thank the crews of the vessels Belgica, Ter Streep, Zeearend, Zeehond and Zeeleeuw or their co-operation. The VLIZ organised some ad hoc surveys on board of the Zeeleeuw. Kees Camphuysen, Mardik Leopold and Robin Brabant dissected the Little Auks and Atlantic Puffins. Jan Seys and Mardik Leopold commented on an earlier version of the manuscript.

DRIE KLEUREN ZWART: DE STRANDING VAN ZEEVOGELS LANGS DE BELGISCHE KUST TIJDENS DE RAMP MET DE *TRICOLOR*

In eerste instantie leek de aanvaring tussen het containerschip de Kariba en het autoschip de *Tricolor* op 14 december 2002 geen negatieve gevolgen te hebben voor de zeevogels in de zuidelijke Noordzee. Pas bij de aanvaring tussen de olietanker de *Vicky* en het wrak van de *Tricolor* (1 januari 2003) lekte er voor het eerst een onbekende, maar kleine hoeveelheid olie in zee. Als gevolg hiervan werden in de eerste weken van januari in totaal 249 met olie besmeurde vogels in het vogelopvangcentrum te Oostende binnengebracht (Tabel 1). Dit was nog maar een eerste voorproef van wat ons te wachten stond. Op 23 februari kwam tijdens de bergingswerkzaamheden van het wrak van de *Tricolor* maximaal 170 ton olie in zee terecht die vele duizenden zeevogels fataal werd. In de periode 23 januari tot 15 februari spoelden in totaal 9177 vogels behorende tot 32 soorten aan op de Belgische kust (Tabel 1). Vrijwel alle vogels waren sterk besmeurd met olie en iets minder dan de helft van de vogels (45,7%) was al dood toen ze werd binnengebracht in het ad hoc opgerichte vogelopvangcentrum te Oostende. Zeekoeten *Uria aalge* (64,0% van alle slachtoffers) en Alken *Alca torda* (22,8%) waren het zwaarst getroffen, gevolgd door niet-geïdentificeerde Zeekoeten/Alken (4,5%), Futen *Podiceps cristatus* (3,4%) en Zwarte Zee-eenden *Melanitta nigra* (1,4%). Andere soorten maakten minder dan 1% uit van de slachtoffers. De soortensamenstelling van de aangespoelde vogels verschilde sterk van de samenstelling die op zee waargenomen wordt. Normaal worden er in de zuidelijke Noordzee verhoudingsgewijs meer meeuwen waargenomen (Tabel 2). Die brengen echter relatief veel tijd door in de lucht en overnachten vaak op land, wat hun minder gevoelig maakt voor olie op zee. Overigens werden tijdens het incident langs de Belgische kust, maar ook tijdens het daaropvolgende broedseizoen in de kolonie te Zeebrugge veel meeuwen gezien met olievlekken op hun verenkleed. Ook werden er om onbekende redenen minder Futen en Roodkeelduikers *Gavia stellata* gevonden dan was verwacht op basis van de aantallen op zee.

Er waren drie piekdagen waarop ongeveer 1000 vogels werden binnengebracht (Fig. 3). Tijdens een eerste piek 4 dagen na het incident werden voornamelijk Zeekoeten (92,5%) gevonden. Die waren grotendeels nog in leven (89,8%) toen ze werden binnengebracht (Fig. 4). Blijkbaar waren de vogels ondanks ongunstige windomstandigheden massaal naar de kust toe gezwommen. Na die eerste piek was het aantal vogels dat per dag op de Belgische kust aanspoelde sterk gecorreleerd met de heersende windsnelheid en –richting (Fig. 3). De twee volgende pieken (op 30 januari en 6 februari) volgden op periodes van harde aanlandige wind. De twee tussenliggende periodes met relatief lage aantallen slachtoffers vielen dan weer samen met aflandige wind.

Er wordt gesuggereerd dat veranderingen in de soortensamenstelling van de olieslachtoffers verband hielden met de bewegingen van de olievlek. Hoe dichter de olievlek bij de kust kwam deste meer kustgebonden vogels zoals Futen er werden binnengebracht (Fig. 4). Beweging van de olievlek evenwijdig aan de kust werden gereflecteerd door de plaats langs de Belgische kust waar de vogels aanspoelden (Fig. 5).

Tijdens de ramp met de *Tricolor* werden veel meer Alken binnengebracht (26,3% van de groep Zeekoet + Alk), dan dat er verhoudingsgewijs op zee aanwezig zijn (13,1%). Bovendien was een relatief groot gedeelte van de Alken al dood bij binnenkomst in het vogelopvangcentrum (62,5% tegen 36,5% bij Zeekoet). Deze verschillen kunnen niet verklaard worden door verschillende overwinteringsgebieden (Fig. 6). Het vermoeden bestaat dat er afgezien van de *Tricolor* slachtoffers ook Alken (en ook Kleine Alken en Papegaaiduikers) zijn aangespoeld die door verhongering om het leven zijn gekomen. Hoewel voor dat laatste geen bewijzen zijn, duidt een soortgelijke massale sterfte door verhongering onder alkachtigen in meer noordelijke gebieden op voedseltekorten in delen van de Noordzee.

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A COMPARATIVE STUDY OF THE DIET OF GUILLEMOTS *URIA AALGE* AND RAZORBILLS *ALCA TORDA* KILLED DURING THE *TRICOLOR* OIL INCIDENT IN THE SOUTH-EASTERN NORTH SEA IN JANUARY 2003

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Ouwehand J., M.F. Leopold & C.J. Camphuysen 2004. A comparative study of the diet of Guillemots *Uria aalge* and Razorbills *Alca torda* killed during the *Tricolor* oil incident in the south-eastern North Sea in January 2003. Atlantic Seabirds 6(3/S.I.): 147-164. In Jan-Feb 2003, some 4000 oiled seabirds washed ashore in The Netherlands following the *Tricolor* oil spill in the English Channel. Hundreds of corpses were collected and transported to laboratory facilities on Texel for autopsies. The opportunity was seized to conduct a diet study on two of the most numerous species among the oil victims, the Common Guillemot *Uria aalge* and the Razorbill *Alca torda*. Of 235 Common Guillemots stomachs that were examined, 59% contained prey remains that could be identified, while only 29% of 156 Razorbill stomachs contained such remains. The present study, the first that directly compares the winter diet of these two auks for the North Sea proper, reports a clear-cut difference in feeding ecology between the two species. Guillemots took a wider variety of prey fish (at least 24 different prey species, including both bottom-dwelling and mid-water species. Razorbills had a much narrower prey spectrum (>8 species). Razorbill diet was largely restricted to Sprats or small Herring. Prey diversity in Guillemots was as least twice as high as in Razorbills involved in the same oil spill. Clupeids (28% by number; 38% by mass), gadoids (20% by number; 47% by mass) and sandeels (31% by number; 10% by mass) were the most important prey in the Guillemots. For Razorbills, clupeids were of prime importance (72% of all prey identified; 88% of prey mass). Sandeels (24% by number; 11% by mass) were of secondary importance, while gadoids were absent in the Razorbill stomachs. Razorbills also had a much narrower prey size spectrum. Of the most commonly taken prey, Sprats and sandeels were on average larger in Guillemots than in Razorbills. The largest prey, Whiting and Herring of over 100 gram each, were predominantly found in adult male Guillemots. Stomachs with substantial prey remains ("full stomachs") were equally distributed over birds with different condition indices, as were completely empty stomachs. Large oiling accidents provide opportunities to conduct large-scale diet studies on several species of seabird simultaneously, but although major oiling incidents have happened time and again, relatively few have been seized to conduct such studies on any seabird. Our study shows also, that the large numbers of oil victims associated with major oil spills, should not be wasted, as they can provide very useful material for diet studies. Collecting sufficient numbers of oil victims should therefore be a priority in clean-up operations that usually follow the fouling of beaches and responsible authorities should be (made) aware of this.

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INTRODUCTION

Between 28 January 2003 and 9 February 2003, some 4000 oiled seabirds washed ashore in The Netherlands following the *Tricolor* oil spill in the English Channel. From the corpses counted during dedicated beached birds surveys that were carried out in response to the incident to assess the damage, a sample was collected and transported to laboratory facilities at the Royal Netherlands Institute for Sea Research on Texel for more detailed investigations including standard autopsies and stomach contents analyses (Camphuysen & Leopold 2004). The opportunity was seized to conduct a diet study on two of the most numerous species among the oil victims, the Common Guillemot *Uria aalge* and the Razorbill *Alca torda*, as little is known on the feeding ecology of these two auks in the southern North Sea. This paper reports on stomach contents of birds involved in this spill.

METHODS

A sub-sample of mainly heavily oiled, intact and rather fresh oil victims was dissected. Standard biometrical data were collected to assess sex, age, body condition at the time of death and possible origin of the casualties (see Camphuysen & Leopold 2004 for details). The amount of oil on the bird was noted for each individual. Un-oiled birds were excluded, as these were not part of this particular oil spill. Stomachs (gizzard and proventriculus) were taken out, bagged individually and kept frozen (-18°C) for later processing. Under the assumption that severely oiled individuals had died quickly and would probably be most useful to study the diet of wintering auks, such corpses were given priority during selection. Corpses from a rehabilitation centre were marked as such, because these birds may have been fed during treatment. However, when their stomachs were examined there were no indications of supplementary feeding and these birds were lumped with the others.

The stomachs were thawed and cut open for analysis. Stomach contents were rinsed with tap water into a glass jar. A controlled and gentle water overflow was used to wash off all organic soft material from the heavier hard parts that could be used for species identification (otoliths, fish bones, squid beaks etc.). All hard prey remains were sorted, dried, identified to the lowest possible taxon and measured if this could be used for prey size estimation. Fish were identified from their sagittal otoliths, pro-otic and pterotic bullae (herring family Clupeidae), atlas vertebrae (sandeels Ammodytidae), vertebrae and denticles (pipefishes Syngnathidae, Hooknose *Agonus cataphractus*, Lumpsucker *Cyclopterus lumpus*), spines (sticklebacks Gasterosteidae) and

Table 1. Correction factors used for worn otoliths (Leopold & Winter 1997, Leopold et al. *2001, Leopold & van Damme 2003).*
Tabel 1. Correctiefactoren om gesleten otolieten te kunnen herleiden tot de oorspronkelijke grootte (Leopold & Winter 1997; Leopold et al. *2001, Leopold & Damme 2003).*

Category of wear	Description	Correction factor
1	pristine (hardly any wear)	5%
2	sulcus and perimeter still intact (some wear)	10%
3	sulcus just visible (considerable wear)	15%
4	external features worn away (heavily worn)	mean size of conspecifics (see text)

preoperculae (dragonets Callionymiidae, Bull-rout *Myoxocephalus scorpius*). Other hard parts such as fish jaws were used when possible. Härkönen (1986), Watt *et al.* (1997), Leopold *et al.* (2001) and the Alterra/NIOZ reference collections of otoliths and fish bones were used for identification and for estimating original fish size and fish mass. *Ammodytes*-sandeels were not identified to species. All *Ammodytes* otoliths were treated as *Ammodytes tobianus* as this species is probably more common than *A. marinus* in nearshore waters of the SE North Sea. Invertebrates were identified from jaws (polychaetes) and horny beaks (cephalopods).

Otoliths were paired when possible and combined with other hard parts to identify individual prey. Fish size was estimated from each individual item (from the same presumed fish) separately, after correction for wear (Table 1) and the mean estimate for fish size was used subsequently. When the size of an identified fish could not be determined (incomplete or badly damaged hard remains), the mean size of that prey species was used instead, as derived from all stomach samples of either Guillemots or Razorbills.

Clupeoid bullae Two types of bullae of clupeids (Blaxter & Hunter 1982) were found: round, pro-otic bullae and potato-shaped pterotic bullae (Figure 1). Pro-otic bullae may come from either Herring *Clupea harengus* or Sprat *Sprattus sprattus*; pterotic bullae are lacking in Sprat. The bullae were sometimes found with clupeid otoliths, and were then matched with these to arrive at a minimum number of (specifically identified) fish for that stomach. However, in many cases bullae were found without clupeid otoliths present and then we followed a different approach. All bullae were classed as either large, medium or small. Large pro-otic bullae were *c.* 3-4 mm in diameter (casing exclusive) and in three cases, were found together with otoliths of large Herring (23.4, 24.9 and 27.6 cm total fish length). Small bullae were 1-2 mm in diameter and were found with both Herring and Sprat otoliths. Medium sized bullae of only three fish

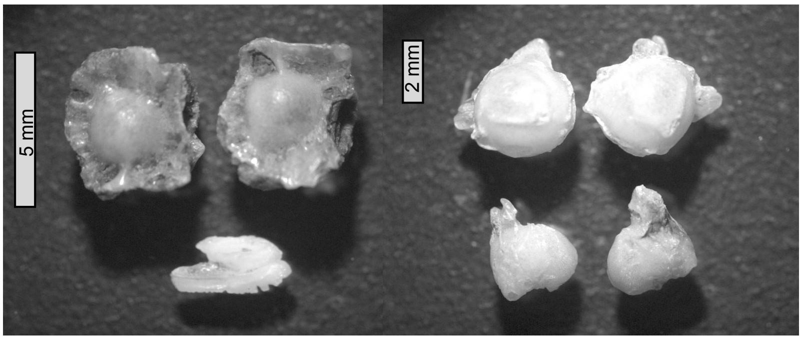

Figure 1. Large pro-otic bullae and Herring otolith (left panel) retrieved from a Guillemot stomach, representing a fish of 23.4 cm total fish length. Right panel: two large pro-otic bullae with two pterotic bullae from another Guillemot sample, representing a similarly sized Herring. Note that wear is more progressed in these bullae. Sprat only have pro-otic bullae but these are no larger than 2 mm in diameter (casing exclusive)

Figuur 1. Pro-otic bullae en otoliet van een grote Haring (23.4 cm lang) uit een maag van een Zeekoet (links). Rechts: een complete set van twee pro-otic en twee pterotic bullae van eveneens een grote haring, uit een andere Zeekoetmaag. Deze bullae zijn van Haring omdat de pro-otic bullae groter zijn dan 2 mm in diameter en omdat Sprot geen pterotic bullae heeft. NB: de bullae in het rechter plaatje zijn meer versleten en hebben daardoor meer van het omliggende bot verloren, maar de bullae zelf zijn nog grotendeels intact.

were found. In the first two cases, combinations of medium-sized pro-otic and pterotic bullae were found in a Razorbill and a Guillemot. In the third case, medium-sized bullae were found in a Guillemot stomach that further only contained the otoliths of an 18 cm long Herring. On this basis, we assigned large pro-otic bullae, all medium-sized bullae and all pterotic bullae to Herring (Table 2). We could now identify all large and medium Herring from either otoliths or bullae, but small clupeids that were only represented by pro-otic bullae could not be further identified. However, as only small pro-otic bullae were found, without any matching pterotic bullae, the vast majority of small clupeids that could only be recognised from the bullae in the stomachs, were probably Sprats.

Table 2. Types, sizes and numbers of clupeid bullae found in the stomachs of Guillemots and Razorbills. Small pro-otic bullae could have originated from either Sprat or small Herring, while all pterotic bullae and medium-sized and large pro-otic bullae originated from medium-sized (circa 18 cm total length) to rather large Herring (21-27 cm on the basis of otoliths found with these bullae).

Tabel 2. Types, grootte en aantallen bullae van haringachtigen zoals die werden aangetroffen in de magen van Zeekoeten en Alken. Kleine pro-otic bullae kunnen afkomstig zijn geweest van kleine Haring of Sprot, terwijl alle pterotic bullae en de grotere pro-otic bullae op basis van de bij deze bullae aangetroffen otolieten afkomstig moeten zijn geweest van Haring met een lengte van ongeveer 18 cm (medium bullae) tot zelfs 21-27 cm (large bullae).

Type	Shape	Size	**Guillemot** *n* fishes (*n* bullae)	**Razorbill** *n* fishes (*n* bullae)	Species
pterotic	potato	M	1 (1)	1 (2)	Herring
pterotic	potato	L	12 (20)		Herring
pro-otic	round	S	39 (70)	119 (231)	Sprat or Herring
pro-otic	round	M	2 (2)	1 (2)	Herring
pro-otic	round	L	23 (41)		Herring

Prey diversity For all prey species length and mass ranges are given in Table 3, with their relative abundance (RA) and frequency of occurrence (FO) in the diets of the Guillemots and Razorbills. In addition, relative mass (RM) was calculated, to weigh the contribution to the total ingested biomass. These indices were calculated according to:

$$RA = \frac{\sum_{k=1}^{s} n_{ik}}{\sum_{k=1}^{s} n_k} \qquad FO_i = \frac{\sum_{k=1}^{s} O_{ik}}{s} \qquad RM = \frac{\sum_{k=1}^{s} m_{ik}}{\sum_{k=11}^{s} m_k}$$

Where n_{ik} = (minimum) number of individuals of prey taxon *i* in stomach *k*

n_k = (minimum) number of individuals of all prey taxa in stomach *k*

O_{ik} = 0 if prey taxon *i* is absent in stomach *k*
1 if prey taxon *i* is present in stomach *k*

m_{ik} = (minimum) of total biomass of prey taxon *i* in stomach *k*

m_k = (minimum) of total biomass of all prey taxa in stomach *k*

s = total number of stomach samples that contained prey

Table 3. Reconstructed prey numbers (n), sizes (as range of total fish lengths, cm) and masses (range, g) in Guillemots. Fish masses of groups denoted with (*) were taken as averages of estimated masses of the relevant fish in the same sample. Fish that could not be identified to species (e.g. "Sprat or small Herring") were only included in the FO-index if no full species of this group (Herring or Sprat) were found in the same stomach.Two smal squid beaks were found, the masses lf these prey were guestimated (**).

Tabel 3. Reconstructie van het aantal prooien (n), de prooigrootte (range, cm) en versgewicht (range, g) van de onderzochte Zeekoeten. De massa van met een asterisk (*) gemerkte prooisoorten werd geschat op basis van het gemiddelde gewicht van de relevante vissoorten binnen de zelfde vogelsoort in het monster. Vissen die niet op soort konden worden gedetermineerd (bijvoorbeeld "Sprot of kleine Haring") werden alleen in de FO-index opgenomen indien in een monster geen enkele prooirest op soort kon worden gebracht. . Er werden twee kleine inkvissnavels gevonden (**); de massa van deze twee prooien kon niet worden bepaald en werd geschat.

Prey species	total *n*	fish length (cm)	fish mass (g)	RA	FO	RM
small Herring						
Clupea harengus	5	7.5 – 11.5	2.6 – 9.6	0.01	0.03	0
large+medium Herring	28	18.0 – 27.6	38.71 - 145.8	0.08	0.17	0.26
Sprat						
Sprattus sprattus	32	7.7 - 15.9	3.1 - 39.6	0.09	0.10	0.06
Sprat or small Herring (*)	39		14.68	0.11	0.10	0.06
Cod						
Gadus morhua	1	17.1	46.8	0	0.01	0
Bib						
Trisopterus luscus	7	11.4 - 19.1	16.9 – 89.5	0.02	0.05	0.04
Poorcod						
Trisopterus minutus	18	10.7 - 16.6	12.5 – 48.1	0.05	0.09	0.05
Bib or Poorcod (*)	2		33.37	0.01	0.01	0.01
Whiting						
Merlangius merlangus	47	12.0 - 27.1	12.9 – 158.8	0.13	0.28	0.37
Three-Spined Stickleback						
Gasterosteus aculeatus	1	7.8	4.1	0	0.01	0
Nilsson's pipefish						
Syngnathus rostellatus	4	< 15	0.5	0.01	0.03	0
Bull-rout						
Myoxocephalus scorpius	2	8.3 - 9.3	7.8 – 11.4	0.01	0.01	0
Hooknose						
Agonus cataphractus	2	14.9 - 14.9	23.9 – 23.9	0.01	0.01	0
Lumpsucker						
Cyclopterus lumpus	1	9	30	0	0.01	0

Prey species	total *n*	fish length (cm)	fish mass (g)	RA	FO	RM
Scad *Trachurus trachurus*	1	14.4	26.8	0	0.01	0
Greater sandeel *Hyperoplus immaculatus*	9	8.9 - 31.6	1.9 – 77.8	0.02	0.06	0.03
Sandeel *Ammodytes marinus* or Raitt's sandeel *A. tobianus*	104	5.0 – 24.0	0.2 – 46.0	0.28	0.36	0.07
Lesser weever *Echiichthys vipera*	1	14.5	37.3	0	0.01	0
Dragonet *Callionymus lyra*	17	5.3 - 12.8	1.0 - 14.0	0.05	0.08	0.01
Reticulated dragonet *C. maculatus*	19	6.6 - 9.8	2.0 – 6.4	0.05	0.03	0.01
Dragonet undet. (*)	3		4.47	0.01	0.02	0
Sand goby *Pomatoschistus minutus*	7	3.4 - 6.3	0.4 – 2.2	0.02	0.04	0
Common goby *P. microps*	7	3.9 - 5.4	0.6 – 1.8	0.02	0.03	0
Painted goby *P. pictus*	1	4.2	0.6	0	0.01	0
Goby undet. *Pomatoschistus sp.* (*)	2	3.7 - 5.7	0.5 - 1.7	0.01	0.01	0
Transparent goby *Aphia minuta*	6	3.9 - 5.1	0.3 - 0.9	0.02	0.01	0
Plaice *Pleuronectes platessa*	1	7.7	4.9	0	0.01	0
Squid undet. (*)	2		5	0.01	0.01	0
Total number of identified prey	369			369 prey	138 stomachs	9882 gram

RESULTS

Prey diversity in Guillemots and Razorbills Of 235 Common Guillemots stomachs that were examined, 59% contained remains that could be identified to specific fish or cephalopod prey (Table 3). A much smaller proportion of Razorbill stomachs (29% of 156 stomachs) contained such prey remains (Table 4). Remains of invertebrates other than squid (one small nereid worm, one small crab and several small bivalve and gastropod molluscs) were considered as secondary (fish) prey or gastrolites and were ignored. Guillemots took a wide variety of prey fish (24 or 25 different prey species in 138 non-empty stomachs), including both bottom-dwelling and mid-water species (Table 3). Razorbills had a much narrower prey spectrum (8 or 9 different species in 45 stomachs). Razorbill diet was largely restricted to Sprats or small Herring (Table 4). Most of these were probably Sprats, judging from the large number of small pro-otic bullae found in Razorbills (while small pterotic bullae were not found Table 2) and the fact that all clupeid otoliths in Razorbills were of Sprat.

Guillemot and Razorbill diets were also compared by calculating the average number of prey species per stomach for either species. For this comparison, we lumped all *Pomatoschistus* gobies, as we were not always certain of specific identification. Average (± SD) prey diversity was 1.53 ± 0.86 species per sample in Guillemots (*n* =138 non empty stomachs) and 1.24 ± 0.53 for Razorbill (*n* = 45), while maximum numbers of different prey species per stomach were 8 and 6, for Guillemot and Razorbill respectively. Although these statistics are rather similar for both species, many more prey species were found in the Guillemots (Tables 3 & 4). Note also, that in the Razorbills only one (species of) *Pomatoschistus* was found, compared to three species in the Guillemots. As the difference in total numbers of prey species found might be related to the much greater sample size in Guillemots we used a bootstrapping routine to examine the effect of sample size on total number of prey found. From the available stomachs with prey, we drew random samples and the procedure was repeated 100 times with replacement, after which average total numbers of prey species were calculated for different sample sizes. Because in both species, quite a few prey species were found in one or only a few more stomachs, the total number of species found increased with the number of stomachs examined and did not reach a plateau in either predator (Figure 2). 90% of the prey species involved would have been found in 35 Razorbill and 110 Guillemot stomachs, respectively. If only 45 stomachs with identifiable prey remains (the sample size for Razorbill) would have been available for Guillemot, 15 (±1.8) prey species would have been found, or 71% of those found in the 138 stomachs that were available for this species. This shows that prey diversity in Guillemots was as least twice as high as compared to the Razorbills involved in the same oil spill.

Clupeids (28% by number; 38% by mass), gadoids (20% by number; 47% by mass) and sandeels (31% by number; 10% by mass) were the most important prey in the Guillemots (Table 3). For Razorbills, clupeids were of prime importance (72% of all prey identified; 88% of prey mass). Sandeels (24% by number; 11% by mass) were of secondary importance, while gadoids were not found in the Razorbill stomachs (Table 4). The Frequency of Occurrence indices corroborate the finding, that clupeids and sandeels were

Table 4. Reconstructed prey numbers (n), sizes (as range of total fish lengths, cm) and masses (range, g) in Razorbills. See Table 3 for conventions.

Tabel 4. Reconstructie van het aantal prooien (n), de prooigrootte (range, cm) en versgewicht (range, g) van de onderzochte Alken. Zie verder de toelichting bij tabel 3.

Prey species	total *n*	fish length (cm)	fish mass (g)	RA	FO	RM
Large+Medium Herring						
Clupeus harengus	1	18.0	38.7	0.01	0.02	0.03
Sprat						
Sprattus sprattus	23	6.2 - 13.2	1.4 – 20.6	0.13	0.22	0.14
Sprat or small Herring (*)	107		8.48	0.59	0.29	0.71
Three-Spined Stickleback						
Gasterosteus aculeatus	2	5.0 - 6.1	1.0 – 1.9	0.01	0.04	0
Scad						
Trachurus trachurus	3	3.2 - 4.1	0.3 – 0.7	0.02	0.07	0
Greater sandeel						
Hyperoplus immaculatus	4	8.0 - 26.6	1.4 - 46.9	0.02	0.09	0.06
Sandeel *Ammodytes marinus* or Raitt's sandeel						
A. tobianus	40	3.4 - 13.3	0.1 – 6.8	0.22	0.18	0.05
Common goby						
P. microps	1	4.3	0.8	0.01	0.02	0
Squid undet. (*)	1			0.01	0.02	0
Total number of identified prey	182			182 prey	45 stomachs	1356 gram

important prey species for both the Guillemot and the Razorbill, while gadoids were also important, but for Guillemot only (Tables 3 & 4).

Prey sizes in Guillemots and Razorbills Razorbills also had a much narrower prey size spectrum. Most prey (166 of 182 fishes) were smaller than 10 cm total length, only one medium-sized Herring (18 cm) and two Greater Sandeels (of 22.2 and 26.6 cm) were larger than 15 cm. In contrast, less than one third of Guillemot prey were smaller than 10 cm (108 of 369), and 64 fishes were larger than 20 cm. Among these large prey were 23 large Herring and 9 Whiting with masses exceeding 100 gram. Of the most commonly taken prey by both Guillemots and Razorbills, both Sprats and *Ammodytes* sandeels were on average larger in Guillemots (Table 5). Again this shows that Guillemots took larger prey (t-tests: Sprat: $t=3.68$, $df=45$, $P<0.01$; sandeel: $t=9.79$, $df=115$ $P<0.01$).

Table 5. Average sizes (± 1 SD, cm; sample size in parentheses) of Sprat and sandeels (excluding Greater Sandeels Hyperoplus immaculatus*) taken by Guillemots and Razorbills. Fish sizes are reconstructed from otoliths found in the stomachs; fishes only represented by heavily worn otoliths were excluded.*
Tabel 5. Gemiddelde grootte (± 1 SD, cm, steekproefgrootte tussen haakjes) van Sprot en zandspiering (Smelt Hyperoplus immaculatus *uitgezonderd) in de magen van Zeekoeten en Alken. Visgroottes werden gereconstrueerd op basis van de in de maag aangetroffen otolieten, waarbij sterk gesleten exemplaren terzijde werden gelegd.*

Prey	Guillemot	Razorbill
Sprat	11.8 ± 2.00 (32)	9.7 ± 2.15 (23)
sandeels *Ammodytidae*	12.8 ± 3.72 (97)	7.8 ± 2.12 (38)

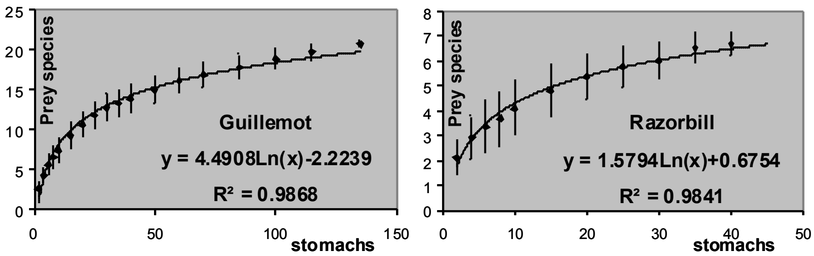

Figure 2. Average (± SD) numbers of prey types that would have been found in different sample sizes drawn from the total sample size of 138 stomachs with identifiable prey remains in the Guillemots (left) and likewise from 45 such stomachs from the Razorbills. A bootstrapping routine with 100 repetitions was used to estimate total numbers of different prey types likely to be found in different sub-sample sizes.
Figuur 2. Gemiddelde (± SD) aantallen prooisoorten dat gevonden zou worden bij een toenemend aantal steekproeven (magen) binnen het totale sample van 138 magen met identificeerbare prooiresten van de Zeekoet (links) of van 45 van dergelijke magen van de Alk. Een bootstrap-routine met 100 herhalingen werd gebruikt om het aantal prooisoorten te schatten bij verschillende monsternames.

Diet versus age and sex in Guillemots Numbers of non-empty stomachs across age classes were only sufficiently large in Guillemots to test the effect of the age or sex of the birds on diet. There was no clear trend in the average numbers of prey species per stomach with age (Table 6).

Adult Guillemots rarely had "full" stomachs (defined as containing fish flesh or >50 loose prey items), but full stomachs were found in a slightly higher proportion of non-adult birds. Of 95 adults with non-empty stomachs, 11 birds

Table 6. Average numbers (with standard deviation and sample size) of prey species identified per stomach in Guillemots of different ages.
Tabel 6. Gemiddeld (± SD) aantal prooisoorten per maag bij Zeekoeten van verschillende leeftijd.

	mean	SD	*n*
Adult	1.52	0.80	95
Immature	1.50	0.82	16
First winter	1.67	1.13	24

had full stomachs, while 7 out of 40 non-adults (immatures and juveniles combined, due to low sample sizes) had full stomachs (χ^2 = 14.93, P<0.005). This difference could be related to diet or to the average time between death and the moment the birds got contaminated with the oil. However, adult and non-adult diets were similar in that relative numbers of small or large Herring, small or large sandeels, dragonets, or gobies per stomach did not differ between age classes (χ^2 tests, P>0.1 in all cases). The only difference found between prey in adults and non-adults was that more adults had taken gadoids (45 gadoids found in 95 stomachs of adults, versus 8 gadoids in 40 non-adults; χ^2 = 5.37, P<0.05). This suggests that diet was not related to the probability of finding full stomachs, as gadoids were relatively large fish that would have taken relatively long to digest. Non-adults thus probably died quicker than adults, once they got contaminated because their prey would normally be digested more quickly, while their stomachs were more often still full.

Of the birds with non-empty stomachs that could be sexed during the autopsies (n=136), 93 (68%) were males. This percentage is close to that for all sexed birds (65% males, n=233) in which we examined the stomach contents. In the males, relatively many very large fishes (Herring or Whiting > 100 gram) were found, but the sample size was not large and this difference disappears if fishes > 50 grams or > 25 grams are included in the comparison (Table 7).

Diet versus condition index and amount of oil on the birds Stomachs with fish flesh or with large numbers (>50) of loose prey items were equally distributed over birds with different condition indices, as were completely empty stomachs, both in Guillemots and Razorbills (χ^2 tests, P>0.1 in all cases where sample size allowed for testing). We also tested whether the probability of finding a gadoid in a Guillemot stomach was related to the condition index of the bird, because gadoids are often considered as lean prey of low profitability. Birds in poor (CI from 0-3; n=38), moderate (4-6; n=71) and excellent condition (7-9; n=119) had similar probabilities of having remains of gadoids in the stomach (χ^2 = 3.07, P>0.1).

Table 7. Numbers of male and female Guillemots with remains of "large" fishes (masses over 100, 50 and 25 gram, respectively) in their stomachs. Given the sex-ratio of all birds with non-empty stomachs (68% males), the difference is only significant (P<0.01) if only fishes with masses exceeding 100 gram are considered.

Tabel 7. Aantallen mannelijke en vrouwelijke Zeekoeten met resten van grote vissen (van minimaal 100, 50 en 25 gram per stuk) in hun maag. Rekening houdend met het percentage mannetjes onder alle Zeekoeten met een niet-lege maag (68%) is het gevonden verschil alleen statistisch significant (P<0.01) als alleen de grootste vissen (van 100 gram of zwaarder) in de vergelijking worden betrokken.

Fish mass	*n*-males	*n*-females	expected numbers		% males	expected %	χ^2
>100	21	3	16	8	88	68	4.69
>50	36	12	33	15	75	68	0.87
>25	49	20	47	22	71	68	0.27

DISCUSSION

Guillemots and Razorbills both raise their chicks on rather small and fatty fish, such as clupeids and sandeels (Pearson 1968; Hedgren 1976; Bradstreet & Brown 1985; Harris & Wanless 1986; Leopold *et al.* 1992; Lyngs 2001). In winter, sandeels spend much time buried in sand and may thus be less available than in the breeding season, forcing the birds to turn to other prey. Winter diets of both species generally show a wider variety of prey species than in summer, including species of lower caloric density such as gadoids, gobies, sticklebacks, pipefishes and even nereid worms (Madsen 1957; Blake 1983, 1984; Blake *et al.* 1985; Durinck *et al.* 1991; Camphuysen & Keijl 1991, 1994; Leopold & Camphuysen 1992; Halley *et al.* 1995; Camphuysen 1998; Lyngs & Durinck 1998; Lorentsen & Anker-Nilssen 1999; Sonntag & Hüppop, manuscript AS). It should be noted, however, that studies in breeding colonies typically look at fish ferried into colonies and fed to chicks, and these might be different from fish eaten by the adults at sea (Camphuysen 2001). Adult Guillemots could take other prey, such as gadoids for self-feeding in the breeding season as well, but this would go largely unnoticed. Indeed, several studies in which adult Guillemots at sea were shot during the breeding and chick dispersal phase showed that gadoids were taken as food (Tasker *et al.* 1986; Anker-Nilssen & Nygård 1987; Leaper *et al.* 1987; Geertsma 1992).

It has been suggested that Sprat and Herring are key species for winter survival of auks (Blake 1984; Harris & Bailey 1992; Skov *et al.* 1992) and both the Guillemots and Razorbills examined here relied heavily on these clupeids.

However, a major and consistent difference between winter diets of Guillemots and Razorbills seems to be, that gadoids form a significant part of Guillemot diet, while Razorbills do not, or to a much lesser extent take these prey. Even if their caloric density is low, gadoids may in fact be profitable prey, as their large size more than makes up for this, as noted by Blake (1984). A large size may also be a constraint, however, both for small chicks in breeding colonies and for full-grown Razorbills. Experimental feeding trials have indicated that Razorbills are less well adapted than Guillemots to swallow large prey (Swennen & Duiven 1977). However, field studies on Razorbill winter diet and especially studies that cover both Razorbills and Guillemots in the same field situation, are rare (Blake 1983; 1984) or include only small numbers of Razorbills (Leopold & Camphuysen 1992) or are based on birds from different locations (Madsen 1957). Our study appears to be only the third that directly compares the winter diet of these two auks and the first that does so for the North Sea proper. We found a clear-cut difference between the two species, in that Guillemots took a much wider variety of prey species and prey sizes, including many relatively large fish (Herring and gadoids, particularly Whiting), while Razorbill diet was largely restricted to Sprat (possibly with an admixture of small Herring). The Razorbills were in excellent physical condition (Camphuysen & Leopold 2004) and this too clearly shows that Sprat was abundantly available in the general area struck by the *Tricolor* oil spill.

It must therefore be concluded that the Guillemots took gadoids because they "wanted" to. Alternative prey (Sprat) was available and it seems unlikely that Razorbills could have outcompeted the larger and more powerful Guillemots. In monospecific studies of Guillemot winter diets it has been suggested that finding large numbers of gadoid otoliths in the stomachs might be an artefact, due to the larger resistance of these thick otoliths to wear. This may be so, but it cannot explain the total absence of gadoid otoliths in the Razorbill stomachs. A physical limitation of Razorbills to catch and/or swallow large fish could explain this absence, but does not clarify why Guillemots take fish that they seemingly avoid in the breeding season. Blake (1984) suggested that the greater ability of Guillemots to include gadoids in their diet could be of great survival value, particularly during adverse winter conditions. In his study of wrecked birds, Razorbills also had taken mainly very small fish (sandeels and Sprat) and they probably had hunted for these in nearshore waters. There is some evidence that also in the Southern Bight of the North Sea Razorbills are comparatively common in nearshore waters (Camphuysen 1998) and this would, with their narrower diet, make the Razorbill a relatively vulnerable species.

Among the Guillemots, the largest fishes (>100 gram) were found predominantly in adult males, suggesting that not all Guillemots are equally equipped to catch and swallow large prey. Although our sample size of large fishes in sexed birds is small (Table 7), this result is largely in agreement with that of Lorentsen & Anker-Nilssen (1999) in their study on the diet of wintering Guillemots drowned in fishing nets in the Skagerrak.

Large oiling accidents provide opportunities to conduct large-scale diet studies on several species of seabird simultaneously, but although major oiling incidents have happened time and again, relatively few have been seized to conduct such studies on any seabird (Blake 1983; Furness 1994; Weir *et al.* 1995; Hughes *et al.* 1997). We had expected to find many birds with full stomachs, as most birds were very heavily oiled and must have died quickly with little time to digest their last meal. This was not found to be the case. Identifiable prey remains were found in less than half of the stomachs and this figure is no better than for wrecked birds as studied by Blake (1984). This suggests that auks do not feed around the clock and that many got hit by the oil some time after their last meal. Given the amount of oil on the birds, it seems unlikely that they suffered long, like many victims of chronic oil pollution that get fouled by smaller amounts of oil, clearly do. Still, a massive oil spill is no guarantee that all stomachs are full of recently ingested fish. Neither was the amount of oil on the bird within our sample related to the probability of finding a full stomach. Interestingly however, Razorbills had fewer full stomachs than Guillemots. This may have been partly related to a difference in diet, as the Razorbills had taken mainly small fish that would have had short retention times in the birds' stomachs. It may also be indicative of a different feeding strategy, with Razorbills only feeding at particular times (e.g. dawn and dusk when clupeids rise from the bottom to mid-water) as opposed to feeding around the clock (including at night, when birds might be more vulnerable to getting oiled).

Our study shows also that the large numbers of oil victims associated with major oil spills should not be wasted, as they can provide very useful material for diet studies. Large sample sizes are required to fully cover the range of prey species, particularly in species with a diverse diet. Such large sample sizes are usually available in full-blown oiling incidents. Our study gave no indication that heavily oiled birds provide better study material than birds that were not fully covered in oil and priority should thus probably be given to collecting adequate sample sizes across species, age classes and sex if possible (e.g. in seaduck). The probability of finding prey in an oil victim could be increased by also inspecting the gut rather than checking the stomach only. In an on-going study on the diet of Red-throated Divers *Gavia stellata* (Leopold *in prep.*), about equal numbers of prey remains are found in the stomach and gut and if the same holds for auks, we would have found about twice the number of prey items, had we inspected the whole digestive track of the birds in our sample. In our diet study, this was not possible as only the stomachs had been taken out of the birds during the general autopsies and when it was realised that many stomachs were empty, it was too late. In any case, oil victims should not be cleared off beaches without further ado, but kept for detailed studies, both to assess the damage on a population scale (see: Camphuysen & Leopold 2004) and to learn more about the diet of these elusive, offshore predators. Collecting sufficient numbers of oil victims should therefore be a priority in clean-up operations that usually follow the fouling of beaches and responsible authorities should be (made) aware of this.

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EEN VERGELIJKENDE STUDIE NAAR DE VOEDSELKEUZE VAN ZEEKOET *URIA AALGE* EN ALK *ALCA TORDA*, GESTORVEN ALS GEVOLG VAN HET TRICOLOR OLIE-INCIDENT IN DE ZUIDOOSTELIJKE NOORDZEE IN JANUARI 2003

In januari/februari 2003 spoelden duizenden zeevogels aan op de kusten van Noord-Frankrijk, België en ZW Nederland, als gevolg van de olieramp van de *Tricolor* in Het Kanaal. Leden van de Nederlandse Zeevogelgroep konden enkele honderden lijken van veelal zwaar beoliede vogels bergen voordat de eveneens zeer actieve opruimploegen dit materiaal samen met de aangespoelde olie van het strand konden verwijderen. Hierdoor kon waardevol materiaal gered worden voor nader onderzoek. Dit materiaal werd door een grote snijploeg op het Koninklijk NIOZ op Texel verwerkt. De talrijkste slachtoffers bleken Zeekoet *Uria aalge* en Alk *Alca torda*, twee soorten die ook onder normale omstandigheden algemeen zijn bij tellingen van olieslachtoffers in het getroffen gebied. Beide soorten komen in de winter talrijk voor in de Zuidelijke Noordzee en lijken zo sterk op elkaar, dat ze tijdens bijvoorbeeld zeetrek- of vliegtuigtellingen vaak niet van elkaar onderscheiden kunnen worden. Een ecologische "wet" zegt echter dat twee soorten niet (lang) dezelfde niche kunnen bezetten. Als dit toch gebeurt zal uiteindelijk één van de twee de concurrentieslag van de ander winnen en deze verdrijven. Over het leven op volle zee van Zeekoet en Alk is echter nog maar weinig méér bekend, dan waar ze zoal voorkomen en in welke dichtheden. Studies aan hun voedselecologie zijn schaars en meestal beperkt tot slechts één van beide soorten. Een olieramp met veel slachtoffers die dik onder de olie zitten (en die dus vermoedelijk snel, soms nog met volle maag zullen zijn omgekomen), in een streek met veel actieve zeevogelaars, vormt dus een buitenkans voor voedselecologisch onderzoek, hoe triest het sterven van grote aantallen olievogels ook moge zijn.

Honderden lijken werden in Zeeland verzameld en er konden magen worden onderzocht van 235 Zeekoeten en 156 Alken. Helaas waren de aantallen magen waar nog herkenbare voedselresten in zaten aanzienlijk lager: respectievelijk 138 (59%) en 45 (29%). Geconsumeerde prooien konden worden gedetermineerd en de prooigrootte kon worden gereconstrueerd aan de hand van allerlei specifieke harde voedselresten. Vaak gaat het daarbij om otolieten (gehoorsteentjes, gemaakt van zeer hard kalkachtig materiaal en met een soort-specifieke vorm aanwezig in alle soorten beenvissen) en bolvormige gasblaasjes van botachtig materiaal (*bullae*) die zich in de schedel van Haring *Clupea harengys* en Sprot *Sprattus sprattus* bevinden.

Zeekoeten en Alken bleken opmerkelijke verschillen in hun menukeuze te vertonen. Zeekoeten hadden een veel breder dieet, zowel in aantallen soorten vissen (zeker twee maal zo veel prooisoorten, gecorrigeerd voor het verschil in aantallen onderzochte magen) als een grotere variatie in de grootte van de gegeten prooidieren. Alken richtten zich zeer sterk op Sprot en wellicht kleine Haring (samen goed voor 72% van alle gevonden vissen; 88% van alle prooimassa). Zandspieringen *Ammodytes* spp. (24% van de aantallen prooien; 11% van hun gezamenlijke massa) vormden de voornaamste aanvulling. In Zeekoeten werden zeker 24 verschillende prooisoorten teruggevonden, waaronder zowel vissoorten die bij de bodem leven als soorten die hoger in de waterkolom voorkomen. Ook voor Zeekoeten waren Haring en Sprot (28% van de totale prooiaantallen; 38% van de totale massa) en zandspieringen (31% van de aantallen; 10% van de totale massa) belangrijk, maar er werden ook veel kabeljauwachtigen (20% van de aantallen en omdat dit vaak relatief grote vissen waren 47% van de totale prooimassa) gevonden. In de Alken werd geen enkele kabeljauwachtige gevonden en ook waren de gevonden haringachtigen en zandspieringen gemiddeld kleiner dan die in de Zeekoeten. Zeekoeten kunnen verrassend grote vissen aan: er werden resten gevonden van 23 haringen en 9 wijtingen van meer dan 100 gram zwaar. De grootste gevonden vissen waren ruim 27 cm lang (Tabel 3). De meeste grote vissen (>100 gram) werden gevonden in volwassen mannetjes Zeekoeten, maar overigens waren er onder de verschillende categorieën Zeekoeten (ingedeeld naar leeftijd, geslacht, hoeveelheid olie op de veren en lichaamsconditie) nauwelijks meetbare verschillen in de voedselkeuze. De aantallen Alken met voedselresten in de maag waren te klein voor dit soort onderlinge vergelijkingen.

Grote olierampen kunnen dus benut worden voor onder meer voedselonderzoek aan zeevogels, onderzoek dat buiten het broedseizoen op andere manieren niet of nauwelijks te doen is. Het interessante van grote olierampen is, dat tegelijkertijd, in hetzelfde gebied, meerdere soorten zeevogels samen kunnen worden onderzocht, waardoor we ook meer te weten komen over hun onderlinge verschillen en overeenkomsten. Overheden geven bij olierampen prioriteit aan het opruimen van de rommel, waarbij dan meestal wel het kind (de vogels) met het badwater wordt weggegooid. Deze studie toont aan dat het de moeite loont om alert te zijn bij olierampen en vogels voor nader onderzoek te verzamelen. Het is zeker, dat we in de toekomst opnieuw te maken zullen krijgen met olierampen, de vraag is alleen: waar en wanneer? Van olievogels valt veel te leren; het is dus zaak om steeds weer alert te zijn bij dergelijke gebeurtenissen. Door onderzoek te doen aan de getroffen vogels kunnen we inzicht krijgen in hun leven op zee, waardoor de dieren dan tenminste niet helemaal voor niets zijn omgekomen.

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