‘Save the North Sea’ Fulmar Study 2002-2004

A regional pilot project for the Fulmar-Litter-EcoQO in the OSPAR area

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ABSTRACT

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North Sea Ministers at the Bergen Conference in 2002 decided that monitoring of marine plastic litter in stomachs of seabirds should become one of the 'Ecological Quality Objectives for the North Sea (EcoQO's)'. The task of implementation was delegated to OSPAR, which covers the wider northeast Atlantic Ocean. OSPAR has requested to expand Dutch studies using the Fulmar (*Fulmarus glacialis*) as a marine litter monitor to the wider North Sea, considering such a project as a pilot study for the introduction of a Fulmar-Litter-EcoQO in the wider OSPAR area.
A North Sea international study of Fulmar stomach contents became possible as a part of the 'Save the North Sea (SNS)' project. SNS is an international and interdisciplinary initiative to reduce marine litter which received cofunding from EU Interreg IIIB program for the North Sea over the years 2002-2004. The Fulmar is used as the symbol of the SNS campaign. The SNS Fulmar study established a research network in all countries around the North Sea. Combined results from Dutch long-term work and the 2002-2004 North Sea study show the Fulmar to be a sensitive and robust monitoring tool for spatial and temporal trends in the marine litter situation that will be of use for EcoQO implementation by OSPAR and the European Marine Strategy.

Keywords: beached-bird-surveys BBS, chemicals, Ecological-Quality-Objective EcoQO, EU-Directive, European Marine Strategy, Fulmarus glacialis, graadmeter, ICES, ingestion, marine litter, monitoring, North Sea, OSPAR, plastic, shipping, stomach-contents

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Summary

In March 2002, ministers of the North Sea countries adopted a system of ***'Ecological Quality Objectives for the North Sea (EcoQO's)'.*** The purpose of the EcoQO approach is to provide quantitative systems to measure major human impacts on the North Sea environment and ecosystem. Such monitoring systems include clearly defined target values to which ecological quality should be restored. Implementation of the EcoQO approach was delegated to OSPAR.

One of the EcoQO's identified in the Ministerial Declaration concerned the marine litter situation in the North Sea for which an EcoQO should be developed based on the monitoring of plastics accumulated in the stomachs of seabirds. OSPAR has identified the Fulmar *(Fulmarus glacialis)* as an appropriate species for the litter EcoQO. The Fulmar is a common seabird within the North Sea and throughout the North Atlantic. Fulmars ingest all sorts of litter from the sea-surface and poorly degradable materials like plastics accumulate in the stomach. Beachwashed birds can be used for study.

OSPAR has broadened the decision by North Sea ministers and aims for implementation of the EcoQO-system in the OSPAR area, that is the whole northeast Atlantic Ocean. The EcoQO approach is also considered in the European Marine Strategy. Working towards wider implementation, OSPAR has asked for a study of regional differences in plastics in Fulmar stomachs in addition to the monitoring work already existing in the Netherlands. A regional study was seen as a pilot for the feasibility of establishing an efficient monitoring system with agreed metrics and specified target values.

An international study of Fulmar stomach contents became possible as a part of the ***'Save the North Sea (SNS)'*** project. SNS is an international and interdisciplinary initiative to reduce marine litter and received cofunding from EU Interreg IIIB program for the North Sea over the years 2002-2004. The Fulmar is used as the symbol of the SNS campaign. The SNS Fulmar study established a research network in all countries around the North Sea and on the Faeroes and can now report on results.

The SNS-Fulmar study has 'de facto' established the monitoring network implementing the Fulmar-Litter-EcoQO for the North Sea as requested by North Sea Ministers in 2002. The combination of Dutch time-series and recent baseline data for the North Sea show that the Fulmar is a robust and sensitive ecological tool to measure regional differences and time-related changes in levels of marine litter in the North Sea and can assist in identifying sources of litter.

Monitoring of Fulmar stomachs in the Netherlands dates back to 1982. Results show that composition of marine litter off the Dutch coast has strongly changed between 1982 and 2003, with strong reductions in industrial plastics, but increases in user-

plastics from garbage and other wastes. Peak levels in user plastics occurred in the late 1990's. In spite of a recent decline, user plastics are still more abundant than in the 1980's.

Regional variation in the North Sea is considerable. When results of separate study locations are combined into larger regions, the southeastern part of the North Sea (Channel exit to German Bight) is currently (2002-2004) the most litter polluted part with an average mass of plastic in Fulmar stomachs close to 0.4 gram (97% of birds affected; on average about 50 pieces per bird). This is about double the level found around the Scottish Isles (0.2 gram; 91%; 20 pieces) with central areas of the North Sea being intermediate (Skagerak; east England). The southeastern North Sea is four times more polluted than the Faeroe Islands outside the North Sea: Fulmars at the Faeroes had on average about 0.1 gram plastic in their stomach (92% of birds affected; 7 pieces per bird). Over the whole of the North Sea 95% of beachwashed Fulmars have plastic in the stomach with an average mass of 0.33 gram and average number of over 40 pieces per bird.

These regional differences lead to the conclusion that marine litter pollution in the North Sea is largely determined by local or nearby sources. All our study regions are exposed to similar 'background'-levels of litter drifting in with the warm Gulf Stream. Local inputs are at least responsible for the up to 4 fold difference between pollution minima and maxima.

With current data, finer scale differences between locations can not be shown to be significant, but results suggest that Fulmar monitoring may have high spatial resolution. Various elements of data suggest that shipping (merchant and fisheries) play an important part in observed litter pollution in the North Sea area indicating potentially high benefit from policy measures in this sector such as the EU Directive on Port Reception Facilities.

Recommendations are made to OSPAR in considering formal implementation of the Fulmar-EcoQO. It is advised to use mass of litter as unit for statistical procedures, in which proper account has to be taken of extreme values in data. Maxima encountered during the SNS study were over 20 grams of plastic in a single Fulmar stomach and over 1600 pieces (cf averages listed above). It is also advised that, even if the EcoQO for simplicity just refers to 'plastic', raw data-collection in the monitoring program should continue to distinguish different categories of plastic as well as non plastic-rubbish and suspected chemical pollutants. Paraffine-like or chemical substances are found in about 25% of Fulmars in the southeastern North Sea. Similar substances are also frequently beachwashed and need further work to assess environmental risks. More detailed research is recommended into differences in plastic loads in Fulmars of different age groups. Material to conduct such a study is available from the Faeroes.

Target values associated with the Fulmar-Litter-EcoQO are a political decision. An informal proposal within OSPAR has tentatively indicated that less than 2% of birds exceeding a limit of 10 pieces of plastic would represent acceptable ecological quality.

In terms of mass, such a limit would be about the equivalent of 0.1 gram of plastic. Our data show that currently 44 to 60% of Fulmars in the North Sea are above such a limit of having 0.1 gram of plastic in the stomach. A political target of reducing this percentage to below 2% seems unrealistic considering the fact that even in Faeroer waters 26% of Fulmars exceeds such a mass-limit. Ten percent may be a more realistic policy target, but the final political decision must also depend on the time schedule for reaching desired levels of ecological quality.

Results in this final SNS Fulmar report for the North Sea show that the implementation of a Fulmar-Litter-EcoQO can provide a robust and efficient policy instrument for OSPAR and the European Marine Strategy in tackling the marine litter problem and improving ecological quality. Fulmars are a sensitive monitoring tool for changes in extent of marine litter pollution, regional differences and sources. The same monitoring tool strongly facilitates acceptance of policy measures among stake-holders and general public because of the convincing message transferred by accumulated human litter in stomachs of birds .

EU Interreg IIIB funding has enabled the implementation of monitoring for the North Sea Fulmar-Litter-EcoQO as requested by the Ministers of bordering countries. However, EU funding for the 'Save the North Sea' project has stopped at the end of 2004, sooner than expected. This means that the North Sea network, continued sampling, data-collection and work towards extension in the OSPAR area are facing collapse, unless immediate alternative funds become available.

Samenvatting

In Maart 2002 werd door de Ministers van de Noordzeelanden besloten tot de invoering van een systeem van ***'Ecological Quality Objectives for the North Sea (EcoQO's)'.*** Met deze Ecologische Kwaliteits Doelstellingen beoogt men te voorzien in een kwantitatief meetsysteem voor de effecten van de mens op het Noordzee milieu en ecosysteem. In de EcoQO benadering ligt besloten dat er een helder gedefinieerde doelstelling is waartoe de ecologische kwaliteit moet worden hersteld. Invoering van de EcoQO systematiek is in handen gegeven van OSPAR.

Eén van de in de Ministeriële verklaring vastgelegde EcoQO's betreft het probleem van zwerfvuil op de Noordzee, waarvoor een systeem ontwikkeld moet worden dat zich baseert op meting van hoeveelheden plastics in de maag van zeevogels. OSPAR heeft de Noordse Stormvogel *(Fulmarus glacialis)* een geschikte soort verklaard. De Noordse Stormvogel is algemeen op Noordzee en de hele noordelijk Atlantische Ocean. Stormvogels eten allerlei soorten afval van het zeeoppervlak en vooral slecht afbrekende materialen als plastics hopen zich op in hun maag. Het onderzoek kan gebruik maken van dood aangespoelde vogels.

OSPAR heeft de beslissing van de Noordzee-Ministers verruimd en richt zich op invoering van de EcoQO systematiek in het OSPAR gebied, d.w.z. de hele noordoost Atlantische regio. Ook de Europese Mariene Strategie onderzoekt het gebruik van EcoQO's. Vanuit deze bredere benadering heeft OSPAR verzocht om een verkennende studie naar regionale verschillen in hoeveelheid plastics in stormvogelmagen, als aanvulling op reeds bestaand monitoringonderzoek aan stormvogels in Nederland. De regionale studie wordt gezien als proefproject voor de mogelijkheid voor de invoering van een breed monitoringsysteem met vastgelegde methodes en EcoQO doelwaardes.

Een dergelijke internationale studie van maaginhouden van stormvogels werd mogelijk als onderdeel van het ***'Save the North Sea (SNS)'*** project. SNS is een internationaal interdisciplinair initiatief dat beoogt zwerfvuil terug te dringen. Het project werd mede gefinancierd vanuit het EU Interreg IIIB programma voor de Noordzee gedurende de jaren 2002-2004. De Noordse Stormvogel wordt gebruikt als het symbool het SNS project. Het stormvogelproject onder SNS heeft een onderzoeksnetwerk tot stand gebracht in alle Noordzeelanden en de Faeroer Eilanden en kan nu over de resultaten rapporteren.

De SNS stormvogelstudie heeft feitelijk het EcoQO-monitoring systeem zoals dat door de Noordzee Ministers werd gevraagd tot stand gebracht. Uit de combinatie van de Nederlandse tijdserie en het internationale SNS onderzoek blijkt dat de stormvogel een degelijk en gevoelig ecologisch meetinstrument vormt voor trends en patronen in ruimte en tijd, en bovendien kan helpen in het identificeren van bronnen van zwerfvuil.

Het monitoren van magen van stormvogels in Nederland gaat terug tot 1982. Resultaten laten zien dat tussen 1982 en 2003 een grote verandering is opgetreden in de samenstelling van zwerfvuil op zee. Industriële plastics zijn sterk afgenomen, maar de gebruiksplastics uit huishoudelijk en ander afval zijn sterk toegenomen. De gebruiksplastics kenden hun piek eind jaren negentig en zijn nadien aan het afnemen, maar de huidige niveaus liggen nog duidelijk boven die van de tachtiger jaren.

Binnen de Noordzee bestaan aanzienlijke verschillen. Wanneer de resultaten van afzonderlijke studielocaties worden gegroepeerd tot regio's, dan blijkt dat de zuidoostelijke regio van de Noordzee (van Het Kanaal tot de Duitse Bocht) in de periode 2002-2004 het meest met zwerfvuil was belast. Stormvogels in dit gebied hebben gemiddeld bijna 0.4 gram plastic in de maag (97% van de vogels is 'besmet'; het gemiddeld aantal stukjes plastic bedraagt ± 50). Dit niveau is ongeveer twee keer zo hoog als rond de Schotse Eilanden (0.2g; 91%; 20 stukjes) terwijl de centrale regios (Skagerak; oost Engeland) daar tussenin liggen. De zuidoostelijke Noordzee is maar liefst vier keer zwaarder vervuild dan het gebied rond de Faeroer Eilanden buiten de Noordzee. Daar hebben de stormvogels gemiddeld 'slechts' 0.1g plastic in de maag (92% besmet; 7 stukjes per vogel). Over het hele Noordzeegebied gezien, heeft gemiddeld 95% van de Noordse Stormvogels plastic in de maag, met een gemiddeld gewicht van 0.33 gram per vogel in meer dan 40 stukjes.

Regionale verschillen leiden tot de conlcusie dat de mate van zwerfvuil in de Noordzee grotendeels wordt bepaald door locale of nabijgelegen bronnen. Al de onderzochte regios zijn blootgesteld aan vergelijkbare achtergrondniveaus van zwerfvuil dat meekomt met de Warme Golfstroom. Locale bronnen veroorzaken tenminste de viervoudige verschillen tussen minst en meest met zwerfvuil belaste gebieden.

Met de huidige gegevens kunnen fijnschaliger verschillen tussen studielocaties niet significant worden aangetoond, maar de resultaten wijzen op een mogelijk hoog oplossend vermogen van het meetsysteem. In de gegevens zitten meerdere aspecten die wijzen op scheepvaart (handels en visserij) als een belangrijke bron van het zwerfvuil. Gerichte maatregelen in deze sector, zoals de EU-Richtlijn voor Haven-Ontvangst-Installaties, kunnen dus een hoog milieurendement opleveren.

Ten behoeve van de formele invoering van een Stormvogel-EcoQO worden een aantal aanbevelingen aan OSPAR gedaan. Geadviseerd wordt om 'zwerfvuil-gewicht' te gebruiken als standaard eenheid in statistische bewerkingen, waarbij op juiste wijze rekening moet worden gehouden met extreme waardes in de gegevens. Maximaal werden in het SNS onderzoek ruim 20 gram plastics in een enkele maag aangetroffen, en meer dan 1600 stukjes (vergelijk gemiddeldes hierboven). Ook wordt aanbevolen om, waar de formele EcoQO zich beperkt tot 'plastic', op de achtergrond metingen te blijven verrichten aan de diverse categoriën plastics, andersoortig afval en mogelijk chemische stoffen. Paraffine-achtige of chemische substanties werden in ± 25% van de stormvogelmagen in de zuidoostelijke Noordzee aangetroffen. Vergelijkbare vervuiling spoelt veelvuldig op stranden aan en nader onderzoek naar milieu-risico's is dringend gewenst. Verder onderzoek wordt tevens aanbevolen aangaande verschillen in maaginhoud tussen verschillende leeftijds-categoriën stormvogels. Daartoe is geschikt materiaal van de Faeroer Eilanden voorhanden.

EcoQO-doelstellingen zijn een politieke beslissing. In een informeel OSPAR voorstel is een voorlopige voorzet gegeven. Doelstelling voor acceptabele ecologische kwaliteit is daarin geformuleerd als de situatie waarin 'minder dan 2% van de vogels een grenswaarde van 10 stukjes plastic in de maag overtreft'. De grenswaarde van 10 stukjes komt ongeveer overeen met een grenswaarde van 0.1 gram plastic. Uit het SNS onderzoek blijkt dat in 2002-2004 maar liefst 44 tot 60% van de vogels in de Noordzee deze gewichts-grens overschrijdt. Een politieke doelstelling die beoogt dit percentage tot onder de twee procent terug te brengen, lijkt niet realistisch gezien het feit dat zelfs rond de Faeroer Eilanden nog 26% van de vogels meer dan 0.1 gram plastic in de maag heeft. Een tien procent doelstelling lijkt realistischer, maar is natuurlijk ook afhankelijk van de termijn waarop het beleid de doelstelling beoogt te realiseren.

De resultaten van deze afsluitende rapportage over de SNS-Fulmar-Studie tonen aan dat invoering van een Stormvogel-Zwerfvuil-EcoQO kan voorzien in een robuust en doelmatig beleidsinstrument voor OSPAR en de Europese Mariene Strategie in hun streven het probleem van zwerfvuil in zee terug te dringen en ecologische kwaliteit te herstellen. Stormvogels vormen een gevoelige graadmeter voor zwerfvuil en de bronnen daarvan. De graadmeter vormt tegelijkertijd een sterk middel voor acceptatie van beleidsmaatregelen onder betrokken partijen en het brede publiek omdat het beeld van zwerfvuil in vogelmagen een overtuigende boodschap overbrengt.

Financiering vanuit EU Interreg IIIB heeft praktische invoering van de Stormvogel-Zwerfvuil-EcoQO zoals gevraagd door Noordzee Ministers mogelijk gemaakt. Helaas is de EU financiering voor het Save the North Sea project, eerder dan verwacht, per december 2004 beeindigd. Dit betekent dat het Noordzee netwerk, het verzamelen van vogels en maaggegevens en natuurlijk een beoogde uitbreiding naar het hele OSPAR gebied in acuut gevaar van afbrokkeling verkeren als niet direct andere fondsen beschikbaar komen.

1 Introduction

1.1 The need for monitoring of marine litter

Economic damage from marine litter affects coastal municipalities that are confronted with excessive costs for beach clean-ups. Tourist business suffers because guests stay away from polluted beaches, especially when litter may pose a health-risk. Fisheries are confronted with bycatch of marine litter which means loss of time for cleaning nets and sometimes the discarding of catch because of tainting. All sorts of shipping suffer financial damage and more importantly, safety-risks from fouled propellors or blocked water-intakes. Finally, coastal litter blowing inland is even seriously affecting farmers. The overall economical damage from marine litter is difficult to estimate, but a detailed study in the Shetlands with additional surveys elsewhere indicates that extrapolated costs for the whole North Sea area may even exceed a billion Euro's per year (Hall, 2000; pers.inf).

Ecological damage from marine litter is most clearly illustrated by entanglement of marine wildlife. Entangled seabirds and marine mammals regularly attract public attention. In summer 2004, the first Humpback Whale found on the Dutch coast proved to be snared and killed by a rope around its neck. When Gannets first established themselves as a breeding species on Helgoland in Germany, the first chick raised was found dead hanging from the nest entangled in the synthetic lining that its parents had used as nest-material. However, only a small proportion of entanglement mortality becomes visible among beachwashed animals.

Even less apparent are the consequences from the ingestion of plastics and other types of litter. Ingestion is extremely common among a wide range of marine organisms including many seabirds, marine mammals and seaturtles. Ingestion causes direct mortality but the major impact may well occur through reduced fitness of many individuals ultimately affecting survival and reproductive success. Sublethal effects on animal populations remain largely invisible. In spite of spectacular examples of mortality from marine litter, its real impact on marine wildlife remains difficult to estimate (Laist, 1987, 1997; Derraik, 2002). Plastics gradually break down to microscopic particle sizes, but even these may pose serious problems to marine ecosystems (Thompson *et al., 20*04) affecting filter-feeders at lower trophic levels.

Thus, marine litter, in particular plastic waste, represents an environmental problem with serious negative economical and ecological impacts.

Recognizing the negative impacts from marine litter, a variety of international policy measures has attempted to reduce input of litter. Examples of these are the London Dumping Convention, 1972; Bathing Water Directive, 1976; MARPOL 73/78 Annex V 1988; Special Area status North Sea MARPOL Annex V 1991; and the OSPAR Convention 1992. In the absence of significant improvements, political measures have recently been intensified by for example the EU-Directive on Port

Reception Facilities (Directive, 2000/59/EC), the Declaration from the North Sea Ministerial Conference in Bergen, March 2002 and subsequent OSPAR Initiatives.

Recent policy initiatives have recognized that policy aims need to be quantifiable and measurable. Therefore, the North Sea Ministers in the 2002 Bergen Declaration (Anonymous, 2002) decided to introduce a system of Ecological Quality Objectives for the North Sea (EcoQO's). A first set of several EcoQO's was to be implemented in an immediate pilot program. For example, the oil pollution situation in the North Sea will be measured by the rate of oil-fouling among Guillemots (*Uria aalge*) found dead on beaches. The ecological quality target is set at a level in which less than 10% of beachwashed Guillemots has oil on the plumage (Camphuysen, 2004).

North Sea ministers identified a second set of EcoQO's for subsequent implementation after 2004. Among this latter group is an EcoQO for marine litter, to be measured by the abundance of plastic in stomachs of seabirds, in casu the Northern Fulmar (*Fulmarus glacialis*). Dutch studies had shown that the acccumulation of plastic in this prominent seabird species could be a useful monitoring tool. Working Groups in ICES and in OSPAR are involved in the further development and implementation of the EcoQO system including the advice on realistic target levels. For convenience the EcoQO for marine litter is referred to as the 'Fulmar-Litter-EcoQO'.

Within the Netherlands, the Ministry of Transport, Public Works and Water Management (VenW) has a coordinating role in governmental issues related to the North Sea environment. As such, VenW is involved in the development of environmental monitoring systems ('graadmeters') for the Dutch continental shelf area. As a part of this activity, already in 2001 VenW assigned a project to Alterra to investigate an early precursor of a Fulmar-Litter-EcoQO for the Netherlands. This pilot project considered stomach contents from Dutch beachwashed Fulmars over the period 1982-2000 and made a detailed evaluation of their suitability for monitoring purposes (Van Franeker & Meijboom, 2002). As findings of that pilot study are the fundament for the current report, relevant elements are reiterated in the next introductory chapter.

1.2 Dutch pilot study on the Fulmar as an ecological monitor of marine litter

Early studies of stomach-contents of Fulmars in the Netherlands and Arctic regions (Van Franeker, 1985) and of related species in the Antarctic (Van Franeker and Bell, 1988) signalled the potential value for monitoring of marine litter. Findings indicated distinctive patterns of quantities of ingested litter that strongly suggested a relation to feeding in areas with different pollution levels. If regional variation in pollution levels was reflected in seabird stomach contents, also temporal changes on a single location should become visible in a monitoring program.

It took until 2001 before this idea could be put to the test. By assignment from the Dutch Ministry of VenW, it was possible for Alterra to reanalyse the Dutch Fulmar stomach contents from the 1980's and compare these to stomachs collected later, in particular the period 1996-2000. Results from this pilot project were published in Van Franeker & Meijboom (2002) and showed the feasibility of stomach contents of beachwashed Northern Fulmars as a tool to measure changes in the litter situation off the Dutch coast in an ecological context.

Reasons for selection of the Fulmar out of a list of potential monitoring species in the North Sea were of a practical nature:

- Fulmars are abundant in the North Sea area (and throughout the North Atlantic and North Pacific) and are regularly found in beached bird surveys, which guarantees supply of adequate samples for research
- Fulmars are known to consume a wide variety of marine litter items
- Fulmars avoid nearshore areas and forage excusively at sea (never on land).
- where other species sometimes regurgitate indigestible items, Fulmars accumulate these in the stomach (digestive processes and mechanical grinding gradually wear down particles to sizes that are passed on to the gut and are excreted).
- thus, stomach contents of Fulmars are representative for the wider offshore environment, averageing pollution levels over a foraging space and time span that avoids bias from local pollution incidents.
- historic data are available in the form of a Dutch dataseries since 1982; and literature is available on other locations and related species worldwide (Van Franeker, 1985; Van Franeker & Bell, 1988).
- Other North Sea species that ingest litter either do not accumulate plastics (regurgitate indigestable remains); are coastal only and/or find part of their food on land (e.g. Larus gulls); ingest litter only incidentally (eg North Sea alcids) or are too infrequent in beached bird surveys for required sample size or spatial coverage (eg other tubenoses or Kittiwake).

Beachwashed Fulmars may have died from a variety of causes. For some birds, plastic accumulation in the stomach was the direct cause of death, but more often the effects of litter ingestion act at sublethal levels, except maybe in cases of ingestion of chemical substances. For other birds, fouling of the plumage with oil or other pollutants, collisions with ships or other structures, drowning in nets, extremely poor weather or food-shortage may have been direct or indirect causes of mortality.

At dissection of birds, their sex, age, origin, condition, likely cause of death and finding date were determined. Stomach contents were sorted into main categories of plastics (industrial and user-plastics), non-plastic rubbish, pollutants, natural food remains and natural non food-remains. Each of these categories has a number of subcategories of specific items. For each individual bird and litter category data were recorded on presence or absence ('incidence'), the number of items, and the mass of items

Although nearly all Fulmars from the Dutch area had plastics and/or other litter in their stomach, the abundance by number/mass of litter was not normally distributed.

Frequency distributions of litter abundance in stomachs were strongly skewed, with over-representation of birds with smaller quantities combined with few birds having extreme burdens of litter in the stomach. Statistical procedures to test for differences between subsamples thus required logarithmic transformation of data. For testing trends over time it was decided to base analytical procedures on all individual data rather than on e.g. annual averages. Otherwise the data for several years of insufficient sample size would have to be discarded. By using individual data all material can contribute to the analysis.

Before looking at time related trends, the pilot study undertook extensive analyses to check whether time-related changes in litter abundance were susceptible to error caused by bias from variables such as sex, age, origin, condition, deathcause, or season of death. If any of these would substantially affect quantities of ingested litter, changes in sample composition over the years could hamper or bias the detection of time-related trends.

Among the variety of factors considered, an important finding of the pilot study was that no statistical difference was found in litter in the stomach between birds that had slowly starved to death and 'healthy' birds that had died instantly (e.g. because of collision or drowning). It would not be unreasonable to expect that slow starvation would force birds to become less selective in food choice, thus leading to more ingested litter. However, as indicated, we could not demonstrate this. Good condition birds had similar quantities of litter as birds that had undergone slow starvation. This means that our Dutch results, which are largely based on beachwashed starved birds, are representative for the 'average' healthy Fulmar living in the southern North Sea off the Dutch coast.

Only age was found to have some effect on ingested litter, adults having somewhat less plastics in their stomachs than younger birds. Possibly, adults loose some of the plastics accumulated in their stomach when they feed chicks or spit stomach-oil during defense of nest-sites. Another factor could be that foraging experience may increase with age. However, our understanding of the observed age difference in plastic accumulation is still poor, and further study should be promoted where possible.

Although age was shown to affect absolute quantities of litter in stomach contents, changes over time followed the same pattern in adults or non-adults. Thus, as long as no directional change in age composition of samples is observed, trends may be analysed for the combined age groups. However, since age may play a role, presentation of results should always include information on age groups.

Analysis of variability in data and Power Analysis revealed that reliable figures for litter in stomachs in the Dutch region were obtained at a sample size of about 40 birds per year and that reliable conclusions on change or stability in ingested litter quantities were possible over periods of 4 to 8 years, depending on the category of litter.

Mass of litter categories, rather than incidence or number of items, should be considered the most useful unit of measurement in the long term, and also is the most representative unit in terms of ecological impact on organisms. Incidence looses its sensitiviy as an indicator when virtually all birds are positive (as is the case in Fulmars). In regional or time-related analyses, mass of plastics is a more consistent measure than number of items, because the latter may vary strongly with changes in plastic characteristics.

The 1982-2000 pilot study detected significant long term trends in incidence, number of items and mass of industrial plastics, user plastics and suspected chemical pollutants (often paraffine-like substances). Over the 1982-2000 period industrial plastics decreased; others significantly increased. When comparing averages in the 1980's to those in the 1990's, industrial plastics decreased by half: from 0.15g per bird (77% incidence; 6.8 granules) in the 1980's to 0.08g per bird (64%; 3.6 granules) in the 1990's. User-plastics increased from 0.19g per bird (84%; 7.8 items) to 0.52g (97%; 27.6 items). Combined for the two categories, plastics had increased from 0.34 to 0.60 grams per bird (incidence from 91% to 98%; number of items from 14.6 to 31.2). Chemical incidence between the decades increased from 10% to 28% (0.18 to 0.53g per bird). An analysis for shorter term recent trends over the period of 1996 to 2000 revealed continued significant decrease in industrial plastics and suggested stabilization or slight decreases in other litter categories. The opposite trends in different types of plastic litter showed that in future monitoring, methods should continue to make distinction between different subcategories of litter.

The pilot study therefore concluded that stomach content analysis of beachwashed Fulmars offered a reliable monitoring tool for (changes in) the abundance of marine litter off the Dutch coast. By its focus on small sized litter in the offshore environment such monitoring has little overlap with, and high additional value to beach litter surveys of larger waste items. Furthermore, stomach contents of Fulmars reflect the ecological consequences of litter ingestion on a wide range of marine organisms and create public awareness of the fact that environmental problems from marine litter persist even when larger items are broken down to sizes below the range of normal human perception.

Formal indicators recommended for a Dutch Fulmar-Litter monitoring system were abundances by mass of industrial plastic, user plastic separately and combined, and suspected chemicals. Each of these represents different sources of pollution, and thus supplies differential information for specific policy measures aiming at reduced inputs. Addition of further formal indicators from other litter (sub-)categories was considered to provide little added value. However, it was recommended to keep basic data-recording procedures such that at the raw data-level, all subcategories continue to be recorded to be extracted from databases, should the need arrive.

1.3 Expanding Fulmar monitoring to the wider North Sea

The Dutch pilot study supported the initiative of North Sea Ministers to decide for the development of a North Sea Ecological Quality Objective (EcoQO) for marine litter using the Fulmar (Anonymous, 2002).

Given the task to implement the EcoQO system, ICES and OSPAR requested a study of regional variability in amounts of ingested litter in addition to the Dutch monitoring. A geographical element was considered necessary for further decisions on the wider implementation of a Fulmar-Litter-EcoQO. Such information was needed for an efficient setup of a wider monitoring network and needed to further specify the metrics to be used and elaborate on sensible target levels for the EcoQO.

Funding to set up a study answering these international questions was found by co-operation in the **'Save the North Sea (SNS)'** project. Save the North Sea is an international network of organisations that wants to reduce marine litter by increasing awareness among users of the marine environment. It is a highly interdisciplinary network combining PR activities, education for youth and stake-holders, clean-up projects (fishing for litter; net-recycling) and research. The Fulmar is used as the symbol in the SNS campaign. The SNS project managed to obtain co-funding from the EU Interreg IIIB program for the North Sea for the period 2002-2004. Alterra's part in the EU-funding was used to set up a network of organisations collecting beachwashed Fulmars from the shores of all North Sea countries and analysing their stomach contents. Types of organisations participating in the Fulmar project varied widely including for example local bird groups, professional bird organisations, universities, government institutes and local beachcleaning teams.

Over the 2002-2004 period, nearly 600 stomachs of Fulmars from around the North Sea could be analysed (more stomachs were collected, but time limits and financial constraints necessitated storage of part of the material). This final report of the Save the North Sea Fulmar study presents the results of the international project. To integrate all information needed for future implementation of the Fulmar-Litter-EcoQO, relevant findings from the Dutch long-term studies have been incorporated. A dedicated final chapter discusses specific implications for EcoQO implementation by OSPAR.

Financial support from the EU Interreg IIIB North Sea program has made this study possible and has established a strong international research network. However, EU support has ended, and alternative finances are urgently needed to ensure the network survival and continued data collection for implementation of the Fulmar-Litter-EcoQO.

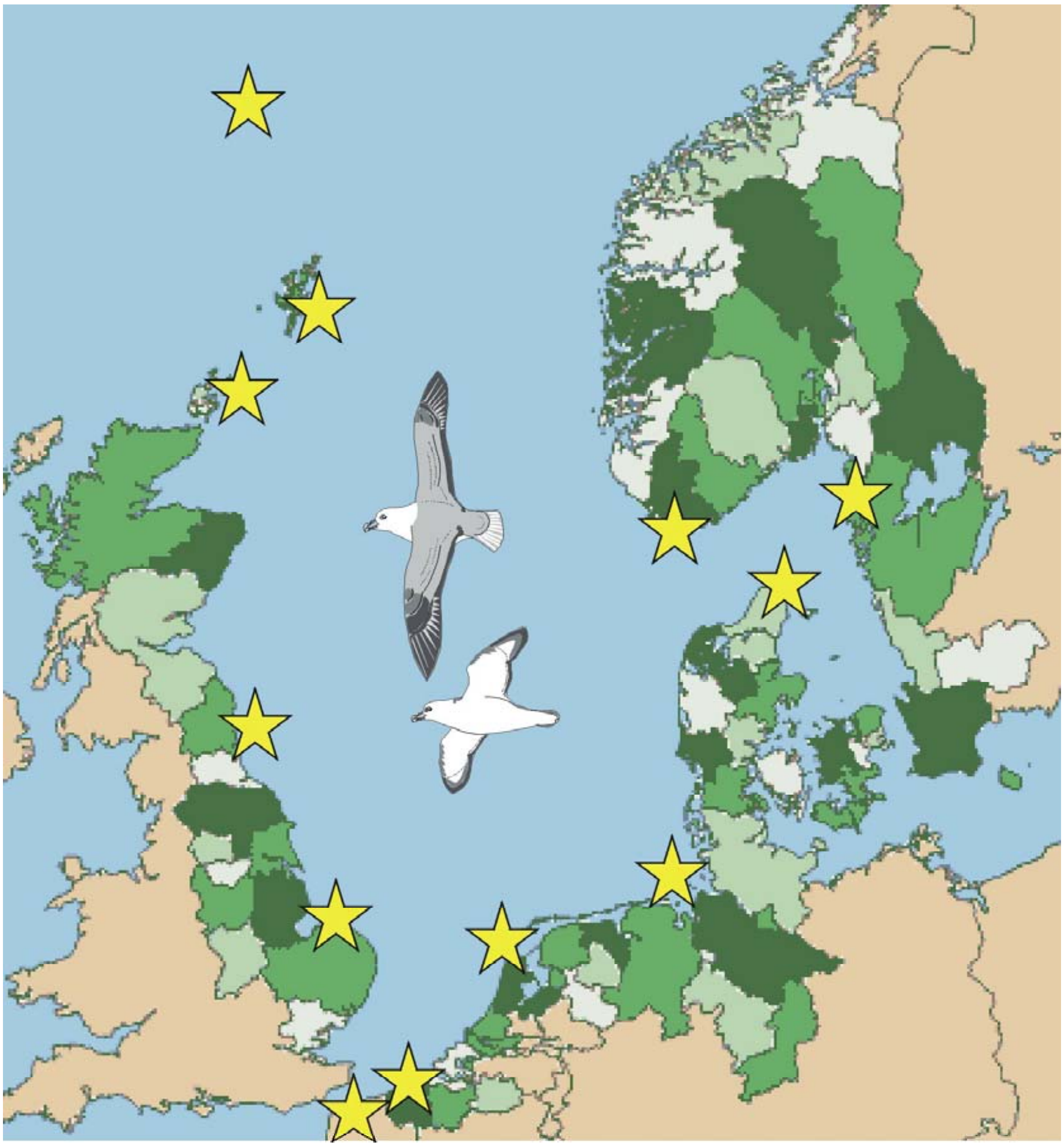


Figure 1. 'Save the North Sea' Fulmar study locations: Shetland Islands, Orkney Islands, northeast England (county Cleveland to north Northumberland), Southeast England (north Norfolk), Belgium, France (Channel coast) Netherlands, Germany (North Sea coast), Denmark (Skagen area), Norway (Lista area) and Sweden (Sotenas area), and as an outside reference, out of the North Sea as defined by Interreg IIIB (green shades): the Faeroe Islands.

2 Material and methods

2.1 Long-term study in the Netherlands

Although this Save the North Sea report mainly concerns the comparative international Fulmar study over the period 2002-2004, an update on the Dutch long term monitoring is equally relevant for further development of the Fulmar-Litter-EcoQO. After the pilot project (van Franeker & Meijboom, 2002) two Dutch updates have been published. The first of these updated the Dutch time-series to include the year 2001 and described the links to the international Fulmar study in the Save the North Sea (SNS) project (Van Franeker & Meijboom, 2003). Recently, a third report updated the Dutch time series to 2003 and discussed the issue of shipping and the implementation of the EU-Directive on port reception facilities (Van Franeker *et al.*, 2004). All reports are available on the internet (www.alterra.nl; www.savethenorthsea.com; www.zeevogelgroep.nl). Results from Dutch studies are summarized in Chapter 3.1, and methods are as described below.

2.2 International SNS-Fulmar study: participants and samples

First contacts on international participation in a North Sea wide Fulmar study were established in 2001. However, actual work could only start after EU-Interreg financial support was confirmed in October 2002. In some areas, where regular Beached Bird Surveys ('BBS') already existed, work could start immediately. In some other areas such surveys still had to be established or alternative ways of collecting stomachs of beachwashed Fulmars had to be found. During the course of 2003 participants in each of the North Sea countries had joined: United Kingdom (Shetland, Orkney and east England), Belgium (including part of French Channel Coast in 2004), Netherlands, Germany, Denmark, Sweden and Norway (Fig. 1). Types of organisations participating in the Fulmar project varied widely and included local bird groups, professional bird organisations, universities, government institutes and local beachcleaning teams. Appendix 1 lists names, affiliations and contact details for all participants. It should be emphasized that in many areas, a huge amount of effort is made by amateur volunteers that patrol beaches and collect the Fulmar corpses suitable for our study, that is the birds that appear to have the stomach intact. It is these volunteers that carry the smelly, and heavy sand- and waterlogged bird-corpses during their long beach transects in order to get them to the freezers of regional co-ordinators.

In addition to the countries situated within the North Sea as defined by the EU-Interreg Program, co-operation was also established at the Faeroe Islands. Even though work in Faeroe was not eligible for Interreg funding, it was decided that the North Sea study was in absolute need of a reference of stomach contents of birds outside the region. Faeroe organisations offered a series of stomachs from birds collected for toxicological research purposes over the period 1998-2002. Of these 38 could be used in the 2002-2004 analysis, whereas 44 earlier samples were also analysed to explore backgrounds of age differences in stomach contents. At the Faeroe Islands, both adults and chicks of Fulmars are harvested for human consumption. From such birds monthly samples of stomachs were obtained throughout 2003. Over 350 stomachs are available for a study of age effects (adults feeding accumulated plastic to chicks) and related seasonal variation in stomach contents of adult breeding birds. Such is important background information for the Fulmar-Litter-EcoQO, but alternative funding is required to process the samples.

Table 1. Number of Fulmar stomachs analysed in this SNS study of regional variation in the North Sea 2002-2004.

	2002	2003	2004	total 2002-2004
Faeroe	38			**38**
Shetland	11	13	17	**41**
Orkney	6	11	6	**23**
NE England		1	4	**5**
SE England			40	**40**
France			36	**36**
Belgium	1	16	68	**85**
Netherlands	56	39		**95**
Germany	3	30	59	**92**
Denmark	1	55	49	**105**
Norway		7	25	**32**
Sweden		6		**6**
total	**116**	**178**	**304** (a)	**598**

(a) *Fulmars suffered mass mortality in March and June 2004 in the southern and eastern North Sea. More beachwashed birds were collected than could be processed within the financial and time limits of the project. An additional number of 29 Belgian and 58 German birds has been stored for later analysis, as well as over 100 birds from the Netherlands awaiting Dutch government funding for analysis. Outside the North Sea monthly sampling was conducted on the Faeroes, with hundreds of samples available for detailed process studies.*

Over the period 2002-2004 and for the purpose of this report, a total of 598 stomachs of Fulmars from the North Sea area and the Faeroes could be analysed. Details per year and location have been specified in Table 1. Annual figures show the increased participation during the project, but the exceptionally high figures for 2004 also reflect unusual mass strandings of Fulmars in large parts of the North Sea in late February, March and also June 2004. Reason for the mass strandings appears to be long-term food shortage for seabirds in the North Sea as evidenced by moult data of Fulmars recorded in the long term Dutch studies and the Save the North Sea project. Preliminary findings were published by Van Franeker (2004a). At this stage it is unclear whether further mass mortalities should be expected in 2005. For future EcoQO purposes, the number of birds collected in 2003 should be seen as an estimate of the number of birds that could be collected annually in the longer term.
Numbers of Fulmar corpses collected in the first half of 2004 were so high, that not all samples could be analysed as time and finances in the SNS project were limited. Thus, part of the material collected in Belgium and Germany has been stored frozen

for later analysis. In Holland well over 100 birds were collected in 2004, but their analysis depends on Dutch funding that has not yet become available. Together with the large Faeroese samples discussed earlier, quite a lot of material is available to further improve data for marine litter monitoring in the Fulmar-Litter-EcoQO.

2.3 Dissection procedures

During the project, three SNS-Fulmar-study workshops have been held at Alterra, Texel, the Netherlands. Each workshop was attended by representatives of nearly every partner in the project. Workshops lasted several days and were used to discuss co-ordination of procedures, analysis of preliminary results, and practical training in the dissection of Fulmars. Dissection procedures, methods for measurements, sexing, ageing etc. were thus calibrated among participants. Based on the experiences from these workshops, a manual has been produced describing methods, standard forms and codes used in the dissection of Fulmars for the Save the North Sea study and future EcoQO monitoring (Van Franeker, 2004b). Details from the manual are not repeated here. Appendix 2 shows the standard form used to record dissection data. Bird corpses are given standardized unique identifiers based on area, year of collection and a sequential number. and are stored frozen by the co-ordinators until analysis. At dissections, a full series of both external and internal anatomical data is recorded and filled in on the standard dissection form. Information collected on the dissection form is of use to determine sex, age, breeding status, likely cause of death, origin, feather-moult status, and other issues. Age, the only variable found to influence litter quantities in stomach contents (van Franeker & Meijboom, 2002) is mainly determined on the basis of development of sexual organs (size and shape) and presence of Bursa Fabricius (a gland-like organ positioned near the end of the gut which is involved in immunity systems of young birds; it is well developed in chicks, but disappears within the first year of life or shortly after).

After recording all external and anatomical data, the stomach is removed. The 'stomach' in Fulmars is the combination two 'units'. First there is a large glandular stomach (proventriculus) in which food is stored and initial digestion starts. Following this proventriculus is a smaller muscular stomach (gizzard) in which harder food remains are grinded until small enough to pass into the gut. The combination of both these stomach parts is removed, cutting the oesophagus above the proventruculus as high as possible, and cutting the gut behind the gizzard. Only complete stomachs were used. Stomachs in which either proventriculus or gizzard was partly missing or damaged by scavenging or decay were discarded for analysis of contents. For full dissection procedures in association with the standard dissection form (Appendix 2), please refer to the manual (Van Franeker, 2004b).

2.4 Stomach content analysis

To ensure full comparability of results in regional comparisons, stomachs from all locations were transported to Alterra on Texel to be analysed by the same team of persons (J.A. van Franeker, A. Meijboom, M.L. de Jong).
Methods for stomach content analyses were described in Van Franeker & Meijboom (2002) but have not yet been published in a dedicated EcoQO manual, because details may still be subject to change in finalizing issues in the EcoQO process. Methodological information from Van Franeker & Meijboom, 2002 is repeated here in a condensed form.

Stomachs of birds are cut open for analysis with either scissors or scalpel. Presence of stomach ulcers and their infection rate with parisitic worms is noted to add to anatomical details recorded at dissection. When considerable quantities of material are present in the stomach, the overall drained weight (DRW) is recorded immediately. If at initial inspection oil or chemical types of pollutants are present, these are first subsampled and weighed. Subsample weight is used to estimate the total mass of the pollutant. Also fragile items are taken out. The remainder of stomach contents is rinsed with cold water in a 1 mm sieve to remove digested unidentifiable prey remains and the mucus from the proventriculus walls. If sticky substances hamper further processing, warm water and detergents may be used to rinse the material as clean as is needed for further processing. Once cleaned, all remaining items are put in petri-dishes for identification and sorting under binocular microscope.

During microscopic identification all items are sorted using the following categorization:

1 **PLASTICS (PLA)**

1.1 **Industrial plastic pellets (IND).** These are small, often cylindrically shaped granules of ± 4 mm diameter, but also disc and rectangular shapes occur. Various names are used, such as pellets, or beads or granules. They can be considered as 'raw' plastic or a half-product in which plastics are usually first produced (mostly from mineral oil). The raw industrial plastics are then usually transported to manufacturers that melt the granules and mix them with a variety of additives (fillers, stabilizers, colourants, anti-oxidants, softeners, biocides, etc.) that depend on the user product to be made. For the time being, included in this category is a relatively small number of very small usually transparent spherical granules, also considered to be a raw industrial product.

1.2 **User plastics (USE)** (all non-industrial remains of plastic objects) differentiated into the following subcategories:

1.2.1 **sheetlike user plastics (she)**, as in plastic bags, foils etc., usually broken up in smaller pieces;

1.2.2 **threadlike user plastics (thr)** as in (remains of) ropes, nets, nylon line, packaging straps etc. Sometimes 'balls' of threads and fibres form in the gizzard;

1.2.3 **foamed user plastics (foa)**, as in foamed polystyrene cups or packaging or foamed polyurethane in matrasses or construction foams;

1.2.4 **fragments (fra)** of more ore less hard plastic items as used in a huge number of applications (bottles, boxes, toys, tools, equipment housing, toothbrush, lighters etc);

1.2.5 **other (oth)**, for example rubber, elastics, cigarette filters etc., so items that are 'plastic like' but do not fit a clear category.

2 **RUBBISH (RUB)** other than plastic:

2.1 **paper (pap)** which besides normal paper includes silver paper, aluminium foil, laminated paper etc., so various types of non-plastic packaging material;

2.2 **kitchenfood (kit)** for human food wastes such as fried meat, chips, vegetables, onions etc, probably mostly originating from ships' galley refuse;

2.3 **various rubbish (rva)** is used for e.g. pieces of timber (manufactured wood); paint chips, pieces of metals etc.;

2.4 **fishhook (hoo)** from either sportfishing or longlining.

3 **POLLUTANTS (POL)** (industrial or chemical waste remains):

3.1 **slags (sla)** that is the remains of burning ovens, e.g. remains of coal or ore after melting out the metals. Often these materials may resemble natural pumice. If doubtful, materials classified as pumice;

3.2 **tar (tar)** is the category for lumps of tarry substances or for more fluid heavy mineral oil;

3.3 **chemical (che)** for lumps of parafine like materials or sticky substances arbitrarily judged to be unnatural and of chemical origin;

3.4 **featherlump (fea)** is used when excessive amounts of preened feathers were found in the stomach, indicating excessive preening by the bird of feathers sticky with oil or chemical pollutants. Presence of a few remains of preened feathers in the stomach is normal and is not recorded under this category. Featherlumps of other species were considered as 'natural food' from scavenging on corpses, unless it was evident that these feathers were heavily polluted.

4 **NATURAL FOOD REMAINS (FOO)**

Numbers of specific items were recorded in separate subcategories (fish otoliths, eye-lenses, squid-jaws, crustacean remains, jelly-type prey remains, scavenged tissues, insects, other), but details of these subcategories are not used in this litter survey study.

5 **NATURAL NON-FOOD REMAINS (NFO)**

Numbers of subcategories plant-remains, seaweed, pumice, stone and other were counted separately, but details are not used in litter analyses. Separately we also made rough estimates of numbers of parasitic worms in the stomach and of 'normal' remains of preened feathers.

After sorting under binocular microscope all above categories, we recorded for each stomach and each (sub)category:

- incidence (Presence or absence) and
- abundance by number (count of Number of items)
- abundance by mass (Weight in grams of airdry material) using Sartorius electronic weighing scale after a one to two day period of air drying at lab temperatures. For marine litter (categories 1 to 3 above) this was done separately for all subcategories, but the natural-food and natural-non-food categories were each weighed as a whole only. Weights were recorded in grams accurate to the 4th decimal (= tenth of milligram).

Appendix 3 shows the standard form used for recording numerical data and further details of stomach contents.

Plastics and rubbish categories that allow dry storage are subsequently stored in a glass jar. Suspect chemicals are stored separately. All litter, except galley foodwaste, is thus stored under the original sample number to have the remains available for later study if warranted by new insights. Identifiable natural food remains are stored as appropriate, either dry (fish otoliths) or in ethanol (squid and worm beaks; zooplankton remains etc) and remain available for dietary study.

2.5 Data-analysis

Data from dissections and stomach content analysis are recorded in Excel spreadsheets and stored in Oracle relational database. GENSTAT 7 was used for statistical tests .

Data characteristics for marine litter were discussed extensively in Van Franeker & Meijboom (2002). Frequency distributions of litter abundance in stomachs are strongly skewed. Most birds have smaller quantities of plastics in their stomach, but in addition a few birds may carry extreme burdens of litter in the stomach. Statistical procedures to test for differences between subsamples thus necessitate logarithmic transformation of data. Transformation remodels data distributions to 'Normal' as required for many statistical procedures. Numbers of items were transformed as ln(x+1), mass-data as ln(x+0.001) in order to include zero counts/masses.

In this report, tables for annual or regional averages are usually presented as 'arithmetic means' or averages. Arithmetic means are directly calculated from the original untransformed values. These may suffer from extreme values, but nevertheless represent the common perception of 'averages'. Where appropriate, to allow comparison between samples, e.g. often in graphs, 'geometric means' are used. Geometric mean is calculated as the average of the ln-transformed data, which is then back-transformed to a normal figure by taking its exponential value and subtracting 1 for numbers of items or 0.001 for mass of items. Since ln-transformation reduces influence of all higher values (not just the few extreme outliers), geometric means are always lower than the arithmetic ones. Usage of arithmetic versus geometric figures is clearly indicated in this report.

Tests for changes over time (Dutch series) were conducted using linear regression analysis of individual ln-transformed values against year of collection. Individual data are used because sample sizes in several years of the time series were too small to use annual averages for testing.

Tests for regional differences were performed using both the original and ln-transformed data. Original data of samples were compared by Man-Whitney U test which ranks the individual values to explore similarity/difference between two sample sets. Ln-transformed data were compared by t-test (95% confidence limits) which explores the comparability of averages from two samples.

Because mass of litter categories is considered to be the most appropriate unit for future EcoQO monitoring, only data for mass of litter were fully tested for trends over time or regional differences. Information on incidence or number of items of litter is usually shown as well, but at this stage those data do not form the basis for comparative conclusions.

3 Results

3.1 Fulmar-litter monitoring in the Netherlands 1982-2003

The most recent update on trends in litter in stomachs of Fulmars beachwashed in the Netherlands was published in Van Franeker *et al.*, 2004, covering the period 1982-2003. Examples and major results are repeated here to illustrate the analysis of trends over time.

Over the 1982-2003 period a total of 479 Fulmar stomachs was analysed. Update reports usually start with providing detailed information on results in the most recent year. Table 2 shows the example from Dutch Fulmars for the year 2003

Table 2. Sample characteristics and stomach contents of Fulmars collected for Dutch marine litter monitoring in the year 2003. The top line shows sample composition in terms of age, sex, origin (by colourphase; darker phases are of distant Arctic origin), death cause oil, and the average condition-index (which ranges from emaciated condition=0 to very good condition=9). Age is currently the only relevant factor potentially affecting results. For each litter-(sub)category the table lists: Incidence, representing the proportion of birds with one or more items of the litter category present; average number (arithmetic) of items per bird stomach; average mass (arithmetic) per bird stomach; and the maximum mass observed in a single stomach. The final column shows the geometric mean mass, which is calculated from ln-tranformed values as used in trend-analyses.

	YEAR	**nr of birds**	**adult**	**male**	**LL colour**	**death oil**	**avg condition**
	2003	**39**	**56%**	**41%**	**87%**	**10%**	**1.2**

		incidence	average number of items	average mass of plastic (g/bird) ± standard deviation		max. mass recorded	geometric mean mass (g/bird)
1	**ALL PLASTICS**	**95%**	**28.54**	**0.169**	**± 0.175**	**0.7**	**0.0677**
1.1	**INDUSTRIAL PLASTIC**	**51%**	**2.28**	**0.045**	**± 0.074**	**0.3**	**0.0068**
1.2	**USER PLASTIC**	**92%**	**26.26**	**0.124**	**± 0.156**	**0.7**	**0.0412**
1.2.1	sheets	46%	1.90	0.004	± 0.013	0.1	0.0010
1.2.2	threads	49%	4.72	0.009	± 0.026	0.1	0.0017
1.2.3	foamed	67%	4.79	0.009	± 0.020	0.1	0.0023
1.2.4	fragments	85%	14.18	0.080	± 0.096	0.4	0.0263
1.2.5	other plastic	26%	0.67	0.022	± 0.075	0.3	0.0013
2	**OTHER RUBBISH**	**10%**	**0.10**	**0.090**	**± 0.424**	**2.5**	**0.0006**
2.1	paper	3%	0.03	0.000	± 0.001	0.0	0.0001
2.2	kitchenwaste (food)	5%	0.05	0.027	± 0.171	1.1	0.0002
2.3	rubbish various	0%	0.00	0.000	± 0.000	0.0	0.0000
2.4	fishhook	3%	0.03	0.063	± 0.393	2.5	0.0002
3	**POLLUTANTS**	**28%**	**1.15**	**2.207**	**± 10.963**	**68.2**	**0.0047**
3.1	slags	3%	0.08	0.000	± 0.001	0.0	0.0000
3.2	tar	0%	0.00	0.000	± 0.000	0.0	0.0000
3.3	suspected chemical	21%	0.92	1.944	± 10.425	65.0	0.0026
3.4	feather lumps	15%	0.15	0.264	± 0.799	3.5	0.0019
4	**FOOD NATURAL**	**90%**	**5.46**	**0.287**	**± 0.985**	**6.1**	**0.0438**
5	**NONFOOD NATURAL**	**79%**	**11.97**	**0.190**	**± 0.240**	**0.9**	**0.0474**

In 2003, the averages for 39 birds were low: although still 95% of birds had plastic, the arithmetic average number of plastic items was only 29, weighing 0.17 gram per bird, and suspected chemicals had been ingested by 21% of birds. Variability in annual values has to be expected in this sort of monitoring. Low arithmetic values for 2003 can in part be explained by the lack of of even a single bird with more extreme stomach contents.

An overview of the important annual figures since 1982 is provided in Table 3. The table shows annual data for incidence and abundance by number and by mass for the three formal litter indicators proposed in the pilot study: industial plastics, user plastics (plus their combined totals) and suspected chemicals.

Table 3 Major litter categories per year 1982-2003. Note sample sizes (n) to be very low for particular years implying low reliability of the annual averages for such years, not to be used as separate figures. Also note variability in age proportions of birds in samples. However, trend analyses are based on values from all individual birds which avoids problems of years of poor sample size or variable age composition. Shown are incidence (%) representing the proportion of birds with one or more items of the litter category present; abundance by number of items per bird (n); and abundance by mass per bird in grams (g) (arithmetic means).

			INDUSTRIAL PLASTICS			USER PLASTICS			ALL PLASTICS (industrial + user)			SUSPECTED CHEMICALS		
YEAR	*n*	% adult	%	n	g	%	n	g	%	n	g	%	n	g
1982	*3*	0%	100%	5.0	0.11	67%	6.0	0.50	100%	11.0	0.61	0%	0.0	0.00
1983	***19***	**39%**	**84%**	**8.8**	**0.19**	**89%**	**7.2**	**0.31**	**100%**	**16.0**	**0.49**	**0%**	**0.0**	**0.00**
1984	***20***	**40%**	**70%**	**9.6**	**0.19**	**90%**	**8.4**	**0.17**	**90%**	**17.9**	**0.35**	**25%**	**0.3**	**0.56**
1985	*3*	33%	100%	5.3	0.14	100%	5.0	0.14	100%	10.3	0.28	0%	0.0	0.00
1986	*4*	25%	50%	0.8	0.02	75%	4.8	0.06	75%	5.5	0.08	0%	0.0	0.00
1987	***15***	**67%**	**80%**	**3.9**	**0.11**	**67%**	**8.9**	**0.09**	**80%**	**12.7**	**0.20**	**13%**	**0.2**	**0.07**
1988	*1*	0%	0%	0.0	0.00	100%	2.0	0.04	100%	2.0	0.04	0%	0.0	0.00
1989	*4*	50%	75%	5.3	0.14	100%	11.0	0.16	100%	16.3	0.29	0%	0.0	0.00
1991	*1*	0%	0%	0.0	0.00	100%	11.0	0.14	100%	11.0	0.14	0%	0.0	0.00
1995	*2*	50%	100%	1.5	0.02	100%	3.5	0.03	100%	5.0	0.06	0%	0.0	0.00
1996	*8*	63%	75%	2.9	0.07	100%	24.5	0.19	100%	27.4	0.26	50%	1.8	1.97
1997	***31***	**16%**	**74%**	**5.9**	**0.13**	**97%**	**29.8**	**0.60**	**97%**	**35.8**	**0.73**	**6%**	**0.2**	**0.00**
1998	***74***	**47%**	**69%**	**3.1**	**0.07**	**95%**	**25.9**	**0.88**	**96%**	**29.0**	**0.95**	**30%**	**1.3**	**1.23**
1999	***107***	**69%**	**58%**	**3.4**	**0.06**	**97%**	**31.8**	**0.38**	**98%**	**35.3**	**0.44**	**33%**	**3.3**	**0.28**
2000	***38***	**58%**	**61%**	**3.4**	**0.08**	**100%**	**18.6**	**0.27**	**100%**	**22.0**	**0.35**	**26%**	**2.4**	**0.06**
2001	***54***	**38%**	**63%**	**2.6**	**0.06**	**96%**	**20.4**	**0.18**	**96%**	**22.9**	**0.24**	**15%**	**0.6**	**1.73**
2002	***56***	**54%**	**68%**	**4.6**	**0.09**	**96%**	**47.2**	**0.41**	**98%**	**51.8**	**0.50**	**23%**	**2.9**	**0.03**
2003	***39***	**56%**	**51%**	**2.3**	**0.05**	**92%**	**26.3**	**0.12**	**95%**	**28.5**	**0.17**	**21%**	**0.9**	**1.94**

However, annual arithmetic means as shown in table 3 are of limited value for the analysis of trends over time. Those require use of individual birds to include data from the intermittent years with small sample sizes, and the analysis should use ln-tranformed data.

Based on the pilot study (van Franeker & Meijboom, 2002), trend analysis has been conducted by linear regression of ln-transformed data on mass of litter against the year of collection. This was done for the categories industrial plastic, user plastic, all plastics combined, and suspected chemicals. Because trends partly appear to have changed since the late 1990's, current analyses look at long-term (1982 to current) as well as recent (1996 to current) trends. Figure 2 gives the example of linear regression analysis on the main category of user plastics. Graphs show individual data points and linear regression trend lines of ln-transformed litter mass against year of collection. The treatment includes repeated tests on different age groups of adults and non-adults (juveniles + immatures). Adults tend to have less plastics in their stomach, and when proportions in age categories would show directional change, this might affect overall results. Graphic presentations of the analyses of other litter catogories are available in Van Franeker *et al.*, 2004. Table 4 gives test results for all major litter types included in the Dutch litter monitoring program.

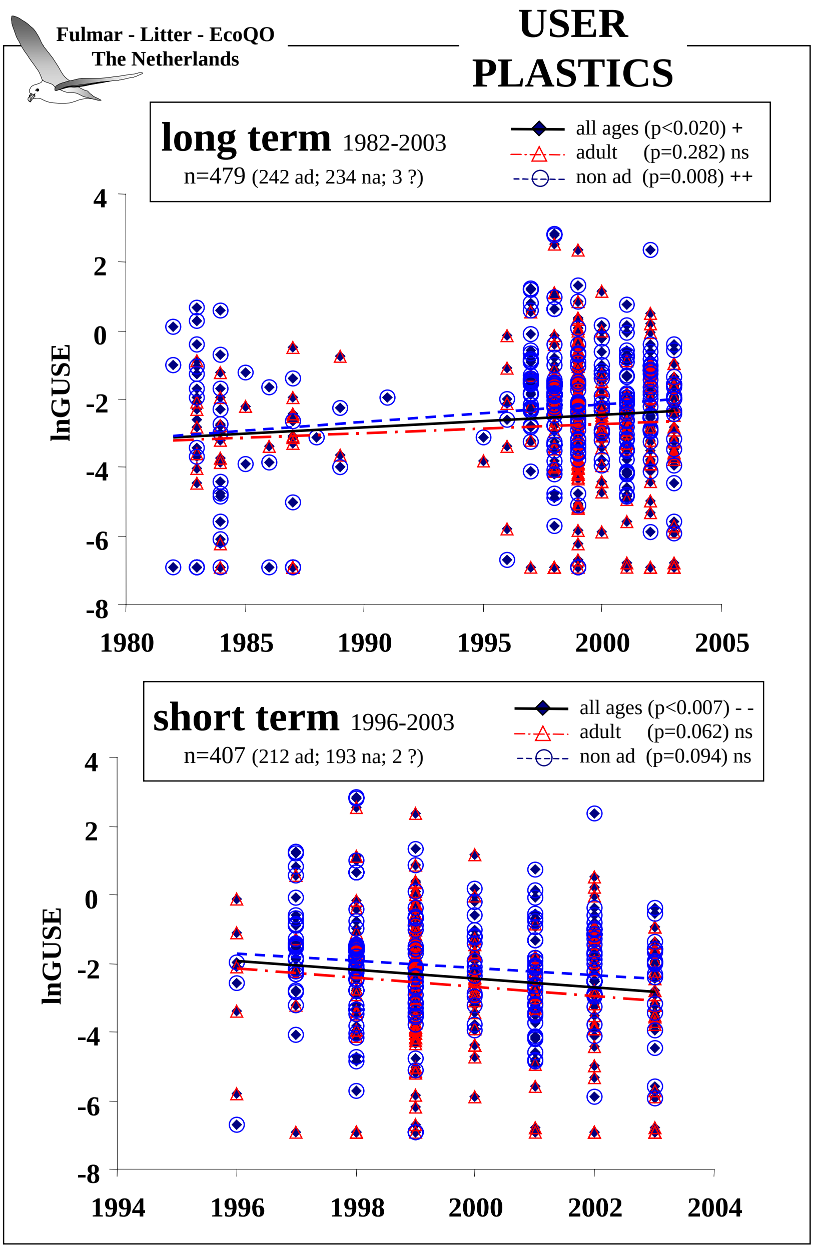


Figure 2. Graphic presentation of analysis of trends over time in the Dutch time series. Shown is the example of analysis for user plastics in which ln-transformed mass of user plastics (lnGUSE) in individual birds is plotted against year of collection. Linear regression lines show trends for all birds, and for separate age groups. Significance of regressions is indicated in the legend.

*Table 4 Details of linear regression analyses of the Dutch litter indicators. Ln-transformed litter mass values for individual birds were fitted on year of collection. The regression line is described by y = Constant + estimate*x. Negative t-values indicate decreasing quantities of the litter category over the years for which the test was performed. Significance (p) of the trend was labelled - or + for significance at level p<0.05; -- or ++ for level p<0.01 and --- or +++ for level p<0.001 for decrease or increase respectively.*

A. LONG TERM TRENDS (1982-2003) in marine litter indicators, The Netherlands

INDUSTRIAL PLASTIC (lnGIND)	*n*	Constant	estimate	s.e.	t	p	
all ages	*479*	138.1	-0.071	0.018	-3.97	**<.001**	- - -
adults	*242*	92	-0.048	0.028	-1.70	0.090	
non adults	*234*	144	-0.074	0.023	-3.23	0.001	- -
USER PLASTICS (lnGUSE)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*479*	-73.8	0.036	0.015	2.33	**0.020**	+
adults	*242*	-54.4	0.026	0.024	1.08	0.282	
non adults	*234*	-107.8	0.053	0.020	2.67	**0.008**	++
ALL PLASTICS COMBINED (lnGPLA)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*479*	8.9	-0.006	0.015	-0.38	0.704	
adults	*242*	-15.7	0.007	0.023	0.29	0.775	
non adults	*234*	2.1	-0.002	0.018	-0.11	0.914	
SUPECTED CHEMICALS (lnGCHE)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*479*	-60	0.027	0.020	1.39	0.165	
adults	*242*	-72.7	0.034	0.032	1.04	0.301	
non adults	*234*	-38.5	0.016	0.024	0.67	0.501	

B. RECENT TRENDS (1996-2003) in marine litter indicators, The Netherlands

INDUSTRIAL PLASTIC (lnGIND)	*n*	Constant	estimate	s.e.	t	p	
all ages	*407*	179	-0.091	0.058	-1.57	0.118	
adults	*212*	10	-0.007	0.086	-0.08	0.933	
non adults	*193*	295	-0.150	0.077	-1.94	0.053	
USER PLASTICS (lnGUSE)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*407*	255.8	-0.129	0.048	-2.71	**0.007**	- -
adults	*212*	270	-0.136	0.073	-1.88	0.062	
non adults	*193*	201	-0.102	0.060	-1.68	0.094	
ALL PLASTICS COMBINED (lnGPLA)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*407*	245.4	-0.124	0.046	-2.71	**0.007**	- -
adults	*212*	196	-0.099	0.071	-1.41	0.160	
non adults	*193*	245	-0.123	0.056	-2.21	**0.028**	-
SUPECTED CHEMICALS (lnGCHE)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*407*	143	-0.075	0.065	-1.14	0.253	
adults	*212*	213	-0.109	0.101	-1.08	0.281	
non adults	*193*	106	-0.056	0.083	-0.68	0.500	

Analyses of long-term (1982-2003) and short-term (1996-2003) trends show that industrial plastic particles offshore the Netherlands have undergone a continuous and significant decrease since the 1980's. The strongest decrease seems to have occurred between the 1980's and 1990's. Since then, these industrial plastics did continue a downward trend, but the rate of decrease is leveling off as within the more recent period the trend is not significant.

Quite differently, user-plastics have shown a signficant overall increase from 1982 to 2003. However, this overall pattern hides an even sharper increase from the 1980's to the 1990's. After peak pollution with user plastics in the late 1990's, the short term trend is significantly downward. The period of decrease however, is not yet sufficient to undo the strong increase in the earlier phases.

Combined for industrial plastics plus user plastics, the partly opposite patterns result in a linear regression analysis that suggests no apparent change in overall plastic pollution between 1982 and 2003. As shown by separate analyses, this ignores a subtantial change in litter composition, in which decreasing industrial plastics have been replaced by increasing user plastics. Also, the long term trend ignores the peak levels in the late 1990's with significant decrease in the 1996-2003 analysis. Linear regression techniques do not provide statistical treatment for curves caused by reversal of trends in a single time-series. This is an issue to be considered in the implementation of the EcoQO metrics in a later phase.

3.2 Regional differences in litter abundance in Fulmar stomachs in the North Sea 2002-2004

For the purpose of the analysis of regional variation, 598 stomachs of Fulmars were analysed (period 2002-2004), of which 560 originate from within the North Sea and 38 from the Faeroe Islands as an external reference (Table 1). More material was available, but for budget reasons not all stomachs could be analysed.

The sequence of locations around the North Sea in graphs and tables is anti-clockwise, that is starting with the Faeroes and Shetland Islands, and ending with Norway and Sweden (Fig. 3).

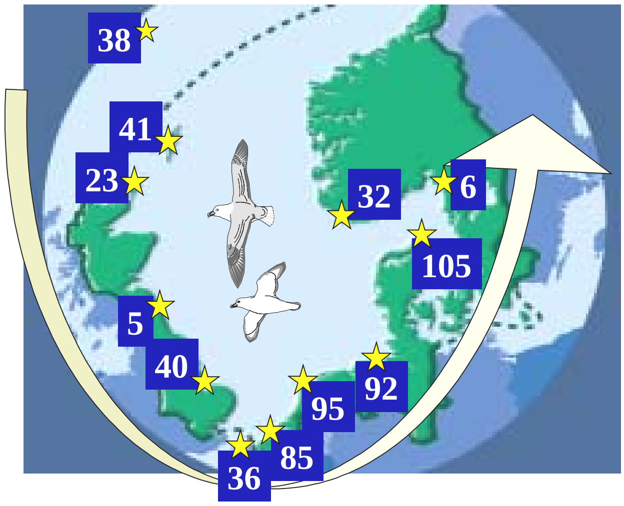


Figure 3 Anti-clockwise sequence of locations in data presentation in tables and graphs in this report (numbers give sample sizes)

Plastics, our main litter category was found to be a common phenomenon at all locations (Table 5). There appear to be very few areas where more than one out of 10 Fulmars is left that has a clean stomach without any plastic. Overall in the North Sea, 95% of Fulmars have plastic in the stomach. The average quantity over all birds is over 40 pieces of plastic per individual with an average mass of 0.33 gram per bird.

Table 5. Occurrence of plastics (industrial plastics and user plastics combined) in stomachs of Fulmars from different locations around the North Sea and Faeroer, in the period 2002-2004.

	number of stomachs in sample (n)	incidence of plastic	average number of pieces of plastic per bird (n)	average mass of plastic per bird (g)	max. (g)	*geometric mean mass (g)*
Faeroes	*38*	92%	7	**0.09**	(0.5)	*0.029*
Shetland	*41*	88%	15	**0.18**	(1.7)	*0.040*
Orkney	*23*	96%	28	**0.28**	(1.2)	*0.076*
Northeast England	*5*	100%	13	0.18	(0.3)	*0.156*
Southeast England	*40*	93%	30	**0.21**	(1.1)	*0.086*
France (north)	*36*	100%	58	**0.25**	(0.9)	*0.137*
Belgium	*85*	98%	74	**0.37**	(4.3)	*0.114*
Netherlands	*95*	97%	42	**0.36**	(11.1)	*0.110*
Germany	*92*	95%	39	**0.35**	(4.3)	*0.101*
Denmark Skagen	*105*	94%	39	**0.38**	(20.6)	*0.071*
Norway Lista	*32*	97%	60	**0.39**	(1.8)	*0.115*
Sweden Sotenas	*6*	83%	48	0.63	(3.0)	*0.071*
North Sea average (all except Faeroes)						
by individuals	*560*	95%	44	**0.33**	(20.6)	*0.092*
by location averages	*11*	95%	41	**0.33**	(20.6)	*0.098*

Variation by individual and by location is considerable. The most extreme case of plastic ingestion was seen in a bird from Skagen with over 20 grams of plastic in the stomach. The maximum number of items was about 1600 tiny pieces in a Belgian Fulmar.

Differences between locations show that fulmars in the North Sea have about two to four times as much plastic in their stomach than Fulmars from the outside reference location at the Faeroes. Figure 4 and Appendix 4 give further detail on samples and pollutants in the stomachs. Industrial plastics occur in roughly 40 to 70% of the Fulmars depending on location, their average number ranging from about 1 to 6 granules per bird and mass from 0.02 to 0.1 gram. Except on the Faeroes and Shetland Islands, user plastics occur in over 90% of birds with average numbers ranging between roughly 10 to 70 pieces and masses from 0.1 to 0.3 gram. Suspected chemical substances are found in 0 to 30% of Fulmars depending on the location. In the chemical category, the 'number of items' is a poor parameter, as substances may just be a sticky soft mud throughout the stomach. In terms of average mass per bird, the chemical category ranges from 0 to 0.8 gram. See Appendix 4 for details on all litter categories at different locations.

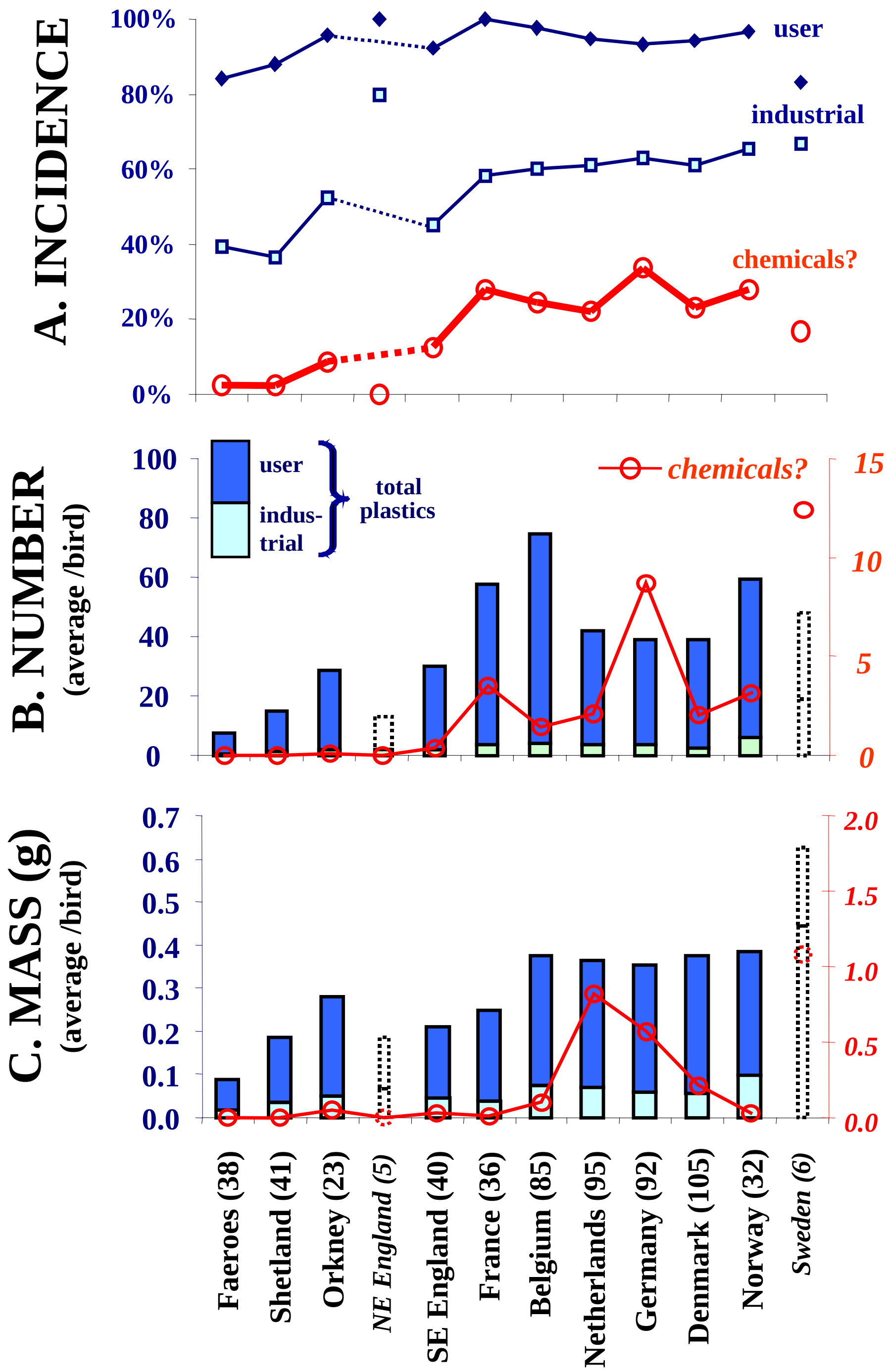


Figure 4. Average (arithmetic) abundance of plastics and suspected chemicals in stomachs of Fulmars from different locations around the North Sea and the Faeroe Islands over the period 2002-2004. Data from northeast England and from Sweden shown by dashed lines because of small sample size.

Some study locations remained below the sample size of ± 40 Fulmar stomachs considered to be an adequate sample to calculate reliable values. Combining bird samples over larger regions solves this problem and also simplifies an overview of the North Sea situation. Locations were arbitrarily combined into 'regions' on the basis of geographical positions (Fig. 5), in which tests for differences between locations were used to assist in decisions of borders (e.g. the decision to keep southeastern England separate from nearby continental locations). Regional data are partly shown in Figure 6 (cf Fig. 4 for same data by location) and detailed in appendix 4b.

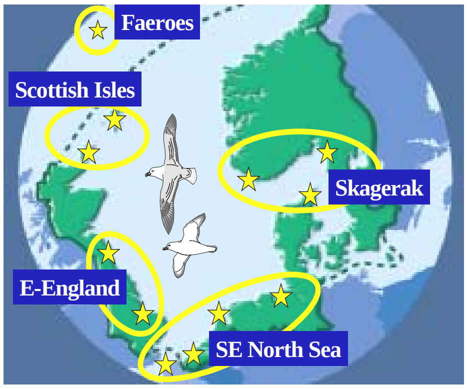


Figure 5. Fulmar study locations grouped into four North Sea regions and the Faeroes.

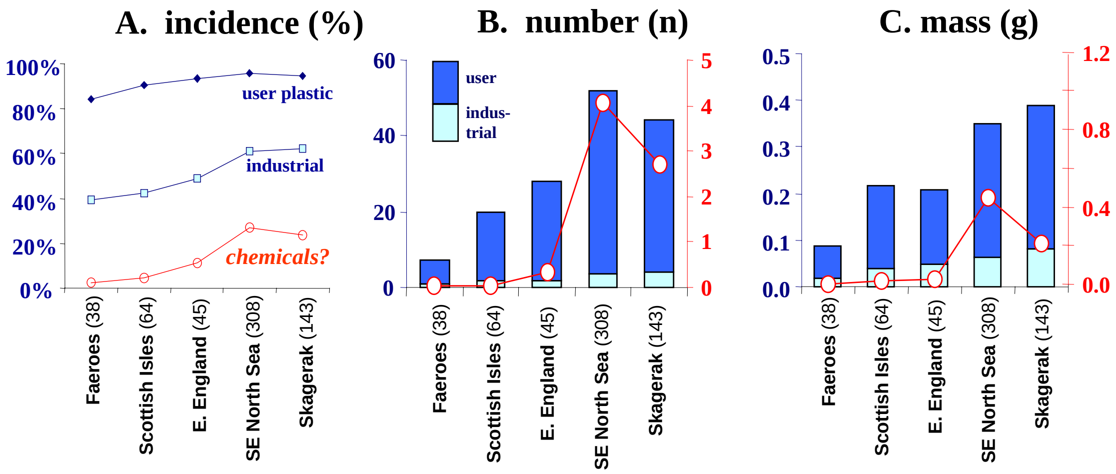


Figure 6. Average (arithmetic) abundance of plastics and suspected chemicals in stomachs of Fulmars from combined regions around the North Sea and the Faeroe Islands 2002-2004.

Data for incidence and the arithmetic means of number and mass of litter items in Fulmars (Figs 4 and 6) give a good first impression of the litter situation around the North Sea. However, like in the analysis of time related trends, conclusive comparisons of differences between locations or regions require a a more detailed approach because original figures have skewed distributions and influential extreme values. Like in trends over time, in the analysis of geographical variation stomach contents, we focus on mass of litter as the most relevant parameter. Figure 7 shows geometric mean masses of litter (calculated from ln-transformed values) for locations and regional groups. Compared with straightforward averages of mass in Figure 4c and Figure 6c, Figure 7 reveals noticeable differences in details between the two types of graphical data presentation.

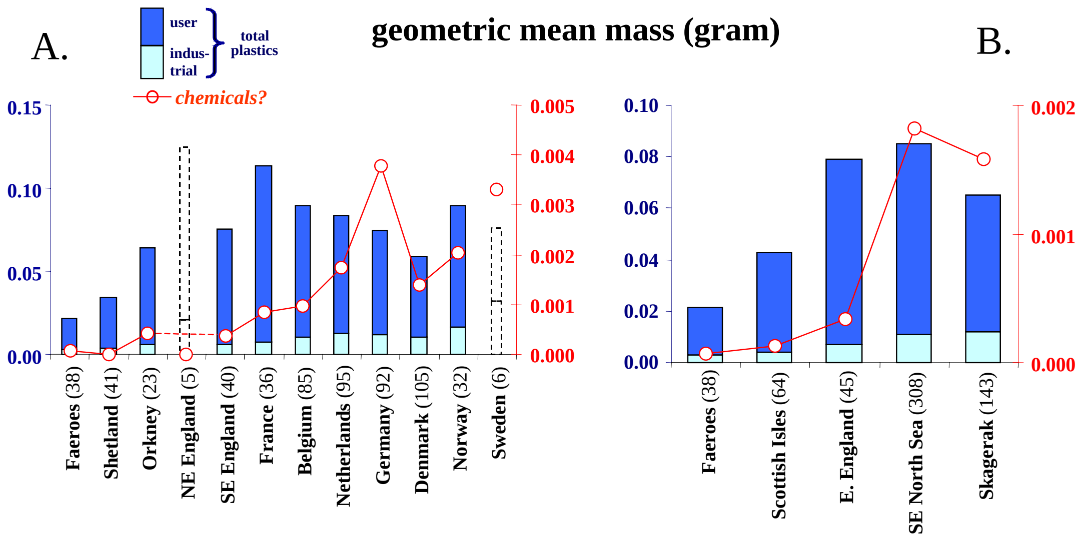


Figure 7. Geometric mean mass of plastics and suspected chemicals in stomachs of Fulmars from around the North Sea and the Faeroe Islands 2002-2004, by separate locations (A.) and combined regions (B.).

Diffferences between samples as maybe suggested by the graphic presentations of arithmetic or geometric means were both tested. Similarity or difference between each possible combination of two locations (or regions) was tested by comparing the individual data underlying the arithmetic or geometric mean of each sample.

The straightforward mass-data underlying arithmetic means (Figs. 4c and 6c) were tested using Man-Whitney U tests. This procedure ranks data in each sample and compares the two sample on the basis of such ranking. Results of Man-Whitney U tests are shown to the right and above of the dark diagional in the matrix of tables 6 and 7.
The ln-transformed mass data underlying geometric means (Figs. 7a,b), were tested using T-tests. The T-test compares whether the means calculated in each of two normally distributed datasets are derived from the same source data. Results of T-tests are shown to the left and below of the dark diagonal in the matrix of tables 6 and 7. Table 6 shows test results for plastics, but is best read in conjuction with table 7 which tabulates test results for all litter types combined (plastic, other rubbish and pollutants). Table 7 emphasizes the underlying patterns.

There is a good agreement in results from Man-Whitney U tests and T-tests in spite of different approaches and data transformation. Both types of test results are best visualised by graphs showing the geometric mean values as in Figure 7. The following pattern of geographical differences between locations emerges.

The Faeroes are significantly different from (cleaner than) all North Sea locations except for the Shetland Islands (in this sort of statements, comparisons with NE England and Sweden are not really considered, as sample.sizes at those locations were too small to expect significant test results).

Table 6 Matrix of test-results exploring sample-differences in mass of PLASTICS for LOCATIONS (A) or REGIONS (B) in the North Sea and Faeroer (2002-2004). Numbers represent the probability p that the two samples compared were drawn from the same 'population'. Significant differences (P<0.05) highlighted by red numbers and yellow filling; near significant differences (0.05<p<0.1) by red numbers only. Man-Whitney U tests applied on mass data (right above dark diagonal); T-tests on ln-transformed mass data (left below of dark diagonal). See text.

A. Man-Whitney U tests on values for mass of plastic (industrial + user) (above diagonal); T tests on ln-transformed values for mass of plastic (industrial + user) (below diagonal)

PLASTICS BY LOCATION	Faeroe (38)	Shetland (41)	Orkney (23)	*NE England (5)*	SE England (40)	France (36)	Belgium (85)	Nether-lands (95)	Germany (92)	Denmark (105)	Norway (32)	*Sweden (6)*
Faeroe *(38)*	1	0.420	0.070	0.032	0.003	<0.001	<0.001	<0.001	<0.001	0.009	0.003	*0.289*
Shetland *(41)*	0.473	1	0.316	0.211	0.088	0.01	0.012	0.008	0.027	0.186	0.039	*0.523*
Orkney *(23)*	0.055	0.242	1	0.521	0.707	0.319	0.391	0.369	0.430	0.882	0.401	*0.773*
NE England (5)	*0.045*	*0.007*	*0.169*	*1*	0.636	0.954	0.745	0.951	0.686	0.354	0.813	*0.931*
SE England *(40)*	0.010	0.087	0.796	*0.475*	1	0.359	0.698	0.576	0.811	0.353	0.665	*0.812*
France *(36)*	< 0.001	0.003	0.203	*0.825*	0.192	1	0.613	0.676	0.521	0.067	0.756	*0.930*
Belgium *(85)*	< 0.001	0.005	0.342	*0.695*	0.416	0.510	1	0.985	0.743	0.099	0.939	*0.969*
Netherlands *(95)*	< 0.001	0.004	0.371	*0.655*	0.462	0.418	0.893	1	0.470	0.049	0.941	*0.950*
Germany *(92)*	< 0.001	0.013	0.511	*0.607*	0.644	0.286	0.668	0.755	1	0.161	0.796	*0.902*
Denmark *(105)*	0.013	0.122	0.855	*0.344*	0.550	0.017	0.070	0.080	0.168	1	0.211	*0.670*
Norway *(32)*	0.003	0.031	0.429	*0.726*	0.509	0.656	0.997	0.899	0.738	0.191	1	*0.922*
Sweden *(6)*	*0.516*	*0.563*	*0.951*	*0.569*	*0.830*	*0.628*	*0.727*	*0.747*	*0.793*	*0.990*	*0.610*	*1*

B. Man-Whitney U tests on mass of plastic (above diagonal); T tests on ln-transformed mass of plastic (below diagonal)

PLASTICS REGIONAL	Faeroe (38)	Scottish Isles (64)	East England (45)	SE North Sea (308)	Skagerak (143)
Faeroe *(38)*	1	0.158	0.0001	<0.001	0.003
Scottish Isles *(64)*	0.177	1	0.118	0.006	0.174
East England (45)	0.004	0.115	1	0.668	0.462
SE North Sea *(308)*	<0.001	0.006	0.493	1	0.071
Skagerak *(143)*	0.005	0.140	0.619	0.055	1

Also the Shetlands are cleaner than all other North Sea locations, often significantly. It is remarkable how different Orkney is in this respect. In spite of spatial proximity to the Shetlands, the Orkneys do not show such strong difference with other North Sea locations. The overall data thus indicate higher pollution levels at the Orkneys than at the Shetlands. Since direct tests did not show such difference to be significant, the Scottish Islands were nevertheless combined into one region because of their proximity. Plastic contents in their stomachs differ significantly from those in southeastern North Sea, and from the Skagerak area if other litter is included.

With the major part of English samples originating from the southern part (Norfolk), not far from southeastern North Sea locations (French Channel to Germany), the decision on grouping of samples into regions became difficult. The apparent jump in geometric mean mass of plastics between SE England and the French Channel (Fig. 7a) was not significant (Table 6a) and differences decreased over the Belgian to German coasts. However, when other litter was included (Table 7a) the English birds did show major differences with France, Netherlands and Germany, and were therefore grouped in different regions. As a region, east England differs significantly from the Faeroes and if all litter is considered also from the SE North Sea. At this 'intermediate pollution level' the English coast has a shared position with the Scottish Islands and the Skagerak area.

Table 7 Matrix of test-results exploring sample-differences in mass of LITTER (plastics, rubbish and pollutants) for LOCATIONS (A) or REGIONS (B) in the North Sea and Faeroer (2002-2004). See caption for table 6 and texts.

A.	Man-Whitney U tests on values for mass of litter (plastics + rubbish + pollutants)											
LITTER BY LOCATION	**Faeroe** *(38)*	**Shetland** *(41)*	**Orkney** *(23)*	*NE England (5)*	**SE England** *(40)*	**France** *(36)*	**Belgium** *(85)*	**Nether-lands** *(95)*	**Germany** *(92)*	**Denmark** *(105)*	**Norway** *(32)*	*Sweden (6)*
Faeroe *(38)*	1	0.420	0.018	0.032	0.003	<0.001	<0.001	<0.001	<0.001	0.002	0.001	0.036
Shetland *(41)*	0.472	1	0.108	0.211	0.067	0.002	0.004	<0.001	<0.001	0.056	0.021	0.133
Orkney *(23)*	0.016	0.101	1	0.908	0.848	0.512	0.655	0.159	0.119	0.744	0.654	0.546
NE England (5)	0.046	0.007	0.399	1	0.661	0.685	0.918	0.370	0.530	0.511	0.914	0.537
SE England *(40)*	0.007	0.066	0.886	0.551	1	0.227	0.491	0.021	0.028	0.739	0.547	0.329
France *(36)*	<0.001	<0.001	0.268	0.883	0.099	1	0.551	0.378	0.394	0.083	0.802	0.793
Belgium *(85)*	<0.001	0.001	0.471	0.89	0.273	0.485	1	0.084	0.112	0.197	0.978	0.601
Netherlands *(95)*	<0.001	<0.001	0.110	0.447	0.028	0.460	0.159	1	0.977	0.001	0.284	0.905
Germany *(92)*	<0.001	<0.001	0.101	0.394	0.025	0.389	0.131	0.889	1	0.002	0.261	0.960
Denmark *(105)*	0.002	0.028	0.895	0.193	0.976	0.037	0.180	0.005	0.004	1	0.347	0.290
Norway *(32)*	0.001	0.015	0.579	0.769	0.412	0.593	0.962	0.290	0.260	0.371	1	0.653
Sweden (6)	0.022	0.089	0.451	0.789	0.349	0.840	0.606	0.981	0.981	0.353	0.637	1
	T tests on ln-transformed values for mass of litter (plastics + rubbish + pollutants)											

B.	Man-Whitney U tests on mass of litter				
LITTER REGIONAL	**Faeroe** *(38)*	**Scottish Isles** *(64)*	**East England** (45)	**SE North Sea** *(308)*	**Skagerak** *(143)*
Faeroe *(38)*	1	0.096	0.001	<0.001	<0.001
Scottish Isles *(64)*	0.118	1	0.179	<0.001	0.088
East England (45)	0.003	0.148	1	0.047	0.905
SE North Sea *(308)*	<0.001	<0.001	0.037	1	0.003
Skagerak *(143)*	<0.001	0.043	0.837	0.005	1
	T tests on ln-transformed mass of litter				

Going north from the French Channel to Denmark, the geometric mean mass data in Figure 7a suggest a decreasing trend in plastic pollution in Fulmar stomachs. Suspected chemicals largely follow an opposite trend. Within this series, subsequent steps are not significant. However, plastic levels in Denmark differ significantly or nearly so from those in France, Belgium and the Netherlands, and if all litter is considered, also the difference Denmark-Germany is significant. These test results, plus geography led to grouping of French, Belgian, Dutch and German data and a separate position for the Danish birds.

The geometric mean mass of plastic in stomachs of Norwegian birds (Fig. 7a) suggests considerably higher levels than at the nearby Danish location. The few birds currently available from Sweden even suggest worse pollution levels. However, with the current sample sizes, statistical tests do not confirm that such a difference is real. For the time being, also because of their close proximity, the Danish, Norwegian and Swedish samples have been combined in the Skagerak region. Combined for the Skagerak, overall litter is significantly lower than in the southeastern North Sea, and nearly so if only plastics are considered.

In conclusion, regional groups (Fig. 7b, Table 7b) show the highest pollution in the southeastern North Sea (French Channel to Germany). Combined for all litter types the difference to all other regions is significant. Intermediate positions are taken by the Skagerak and east England, with the Scottish Islands being the cleanest North Sea location. Further away, Faeroer birds carry significantly less plastics and other litter than birds from the Orkneys, but for the combined Scottish Islands the difference to Faeroer is not significant.

In comparison to arithmetic averages (Figs 4 and 6), geometric mean data (Fig. 7) appear the better way to visualize differences between samples because they give a better representation of the test results in Tables 6 and 7. However, the significance of differences between samples was shown equally well when using original mass data in Mann-Whitney U tests or when using ln-transformed data in T-tests.

4 Discussion

4.1 Marine litter trends 1982-2003 in Dutch Fulmars

Graphs and tables in Dutch litter monitoring, presented in part in chapter 3.1, are required as proper background documentation for the data and analysis of trends. However, a tool intended for easy understanding by the general public, stake-holders or politicians, needs a condensed and clear summary. Therefore, in the Dutch 1982-2003 report (Van Franeker *et al.*, 2004), the information was summarized as in Figure 8, giving a general impression of incidence, numbers and mass of litter since the start of the time-series in 1982. In a more condensed form, only Figure 8c (litter mass) can be shown.

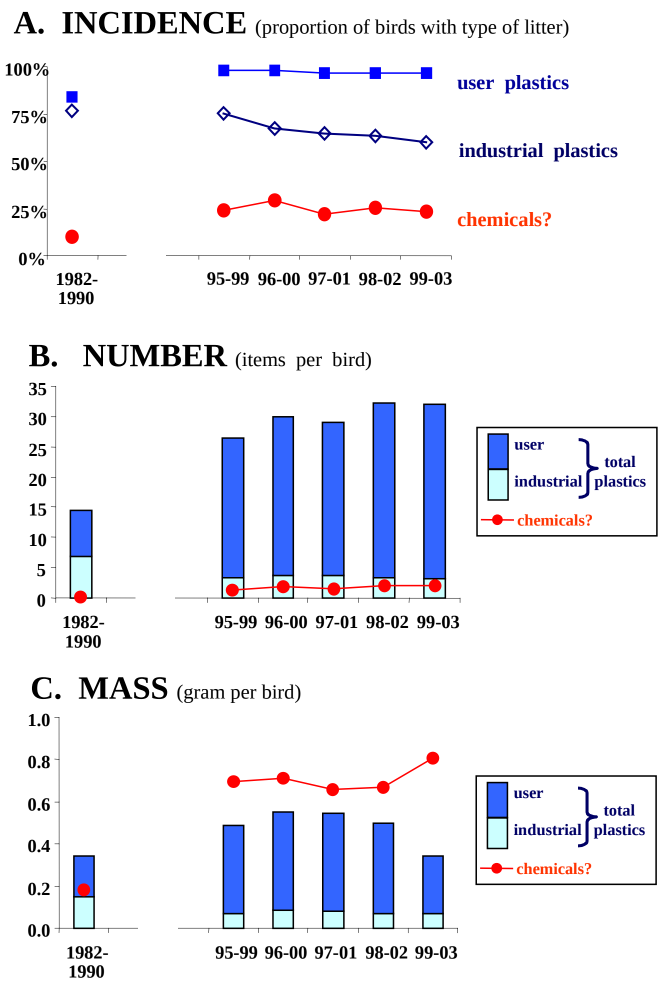


Figure 8. Summary results of Dutch Fulmar Litter monitoring over the period 1982-2003 showing the average situation (arithmetic data) in the 1980's for plastics and suspected chemicals in comparison to running 5-year averages from annual figures since 1995.

The summary presentation in Figure 8 uses running 5-year averages for the more recent period in which annually good sample sizes were studied. Averageing of annual figures smoothes short-term interannual differences. The 5 year average was arbitrarily chosen because that optimally visualized results of statistical trends in understandable units of measurements. In the recent situation (average over 5 last years; 294 birds) 98% of Dutch Fulmars have plastics in the stomach, with an average number of 32 pieces and average mass of 0.34 gram per bird. Associated statements on significance of trends are solely based on the detailed analyses of mass of litter.

The conclusion from (mass)indicators is that in recent years the overall plastic litter situation in the southern North Sea tends to return to levels similar to those during the early and mid 1980's, after peak litter abundance in the years 1997-99. However, within this overall pattern there are different trends for different types of plastic. Industrial plastics have shown a steady decrease throughout, although recent data suggest that the rate of decline is slowing down. User plastics initially showed a sharp increase but after the late 1990's this trend has reversed. Nevertheless, quantities of user plastics are still considerably higher than in the early 1980's. So even if the overall mass of plastics in recent years shows similarity to that in the 1980's, there has been a significant change in composition, which emphasizes the need to continue monitoring of separate subcategories of litter.

Conclusions from analyses of data on mass are confirmed by data on incidence (Fig. 8a), but not by data on number of items (Fig. 8b). The number of plastic items does not show a decrease since the late 1990's. Apparently, the character of user plastics has shifted towards smaller pieces. Possibly this reflects a change in type and character of commonly used plastics, but other factors may be involved like the usage of waste grinders (see Chapter 4.3). The divergence in recent trends re-emphasizes the need for a clear choice in unit of measurement: as indicated we consider mass data as the more relevant parameter in terms of input of litter in the marine environment, and also the more relevant one in terms of ecological impact in effects on marine organisms like Fulmars.

The long term and consistent decrease in industrial plastic pollution is most likely related to ongoing improvements in procedures in factories and waste-water systems and to the increased container-transport in marine shipping replacing loose bags in stowed cargo. To manufacturers and transporters, reduction of losses of industrial plastic granules represents a direct economic benefit.

The gradual reduction of the hard industrial plastic granules from the marine environment is remarkable. Wear and degradation were anticipated to be low, and during the 1980's led to a pessimistic view that even major reductions in input would be unable to prevent further accumulation in the marine environment. Our data show that this has not occurred. The trends indicate the combined effect of reduced input and of unexpected pathways of disappearance. Possibly large quantities of industrial plastic granules become buried in coastal soils. However, considering the rates in which birds consume industrial plastic pellets, one has to consider the wear and degradation in bird digestive tracts as a realistic pathway of 'disappearance' from the marine environment. Unfortunately this is a largely cosmetic effect, because the plastic is not really digested but is merely reduced to a smaller, less conspicuous size of fragments that can still affect marine organisms (Thompson *et al.*, 2004).

The economic benefit of reducing losses does not apply to user plastics or other garbage. In marine shipping, household type or cargo related wastes represent a cost factor in terms of handling effort, stowage space and fees charged for disposal ashore. Disposal at sea has been the cheaper option, only counteracted by the (low) risk of being caught and fined for violations. This cost factor did not change significantly with the entry into force of MARPOL Annex V (1988) or the designation of the North Sea as a 'Special Area' (1991) under this annex. In principle the EU-Directive on Port Reception Facilities (Directive 2000/59/EC) has the potential to influence the cost aspect for ships, depending on its practical implementation by harbours. The Directive entered into force formally in December 2002 but implementation suffered delay and can not explain the improvement seen after the late 1990's. At the moment there is no obvious explanation why litter input from shipping or other potential sources has decreased in recent years. In the Dutch situation, shipping (merchant, fisheries and other) is considered to be a major source of marine litter (Van Franeker *et al.*, 2004).

The shift in relative abundance of different types of plastic seen in the Netherlands is probably not limited to the North Sea but may occur worldwide. Vlietstra & Parga (2002) obtained very similar results in the north Pacific area. Stomach contents of Short-tailed Shearwaters (*Puffinus tenuirostris*) showed a change in type of plastic with a reduced proportion of industrial granules, but not in overall quantity.

Abundance of suspected chemical substances in Fulmar stomachs seems to have increased between 1980's and late 1990's but does not show a clear trend. Roughly 25% of Dutch beachwased Fulmars has such substances in the stomach. Since it is likely that such substances quickly disappear into the gut, the observed frequency of occurrence suggests high rates of ingestion. Similar substances are increasingly found on beaches and commonly depicted as 'paraffine' or 'palm-oil' incidents, without further investigation Characterization of substances involved, and potential effects of ingestion, are urgently required.

Dutch Fulmar monitoring has shown that stomach contents of Fulmars are suitable to monitor changes over time in the offshore marine litter situation. Fairly rapid changes in different plastic categories indicate that reduced input has measurable effect on the marine environment in a time-span shorter than the life-expectancy of most plastic materials might suggest.

4.2 Geographical litter differences in North Sea Fulmars 2002-2004

In the initial phase of the SNS Fulmar project, the expectation was that within the North Sea area only minor differences would exist in amounts of litter in Fulmar stomachs. High mobility of Fulmars and long residence times of plastics in stomachs were thought to counteract strong differentiation within the area.

Results of the study show that the initial expectation was incorrect. Considerable differences were found even between nearby locations. Usually, differences from one location to the next were not statistically significant, but lack of significance may well be related to the relatively short period of our study and consequently insufficient sample sizes. Location differences are discussed further in Chapter 4.3.

When locations were combined into larger regions an overall picture emerges from which the conclusion on regional differentation in litter levels is beyond doubt. The evidence from just plastics (Table 6b) is still incomplete, but when all litter types in Fulmar stomachs are considered (Table 7b), a strong gradient from most severe pollution in the southeast to lowest pollution in the northwest is evident. Only the regions halfway in this north-south gradient on the opposite sides of the North Sea, England and the Skagerak, can not be distinguished from each other.

To quantify these differences, geometric mean masses (gmm) for the different regions (Table 8) show that the lowest plastic loads in North Sea Fulmars (Scottish Islands: gmm 0.050g) are about twice the level as outside the North Sea (at the Faeroe Islands: gmm 0.029g). Within the North Sea, Fulmars in the southeastern part have double the amount of plastics (gmm 0.111g) as compared to those at the Scottish Islands and four times compared to those at the Faeroes. Due to data characteristics discussed earlier, it is not easy to quantify the differences in normal averages (arithmetic means). Roughly, the average Faeroer Fulmar has less than 10 particles and less than 0.1g of plastic in the stomach.; Fulmars in the cleanest North Sea areas average at about 20 particles and 0.2 gram; finally birds in the most polluted parts of the North Sea average at about 50 particles and 0.4 gram of plastic per bird stomach.

Table 8. Occurrence of plastics (industrial plastics and user plastics combined) in stomachs of Fulmars in major regions of the North Sea and Faeroer, in the period 2002-2004

	number of stomachs in sample (n)	incidence of plastic	average number of pieces of plastic per bird (n)	average mass of plastic per bird (g)	max. (g)	*geometric mean mass (g)*
Faeroes	*38*	92%	7	**0.09**	(0.5)	*0.029*
Scottish Isles	*64*	91%	20	**0.22**	(1.7)	*0.050*
East England	*45*	93%	28	**0.21**	(1.1)	*0.092*
Souteast North Sea	*308*	97%	52	**0.35**	(11.1)	*0.111*
Skagerak	*143*	94%	44	**0.39**	(20.6)	*0.079*

The first conclusion from the regional pattern is that the Fulmar as a monitor of marine litter has a higher spatial resolution than anticipated. This indicates that Fulmars around the North Sea are probably less mobile than their excellent flying capabilities might suggest. Apparently, on average, birds tend to stay around particular foraging areas for longer periods of time. Regional and location differences also indicate that accumulated plastics in stomachs may have a shorter residence time than often thought.

Second conclusion from the regional pattern is that marine litter pollution in the North Sea is largely determined by local or nearby sources. The southern North Sea and northern Scottish waters, and even the Faeroes are largely fed by the same Atlantic Gulf Stream. Undoubtedly some litter is coming to our area with Gulf Stream waters, but the large regional differences within the North Sea evidence of major local inputs in western Europe on top of background levels from distant sources. Consequently, regional policies to counteract input of marine litter have good potential to be effective.

Thirdly, the regional pattern suggests that marine litter including plastics may disappear more quickly from the sea surface than anticipated. Residual currents in the North Sea flow from the Channel area towards the Skagerak. If all litter remained available, the residual current plus additions from underway litter sources would cause highest levels of pollution to be expected near the Skagerak. The fact that we do not find this in our data suggests fairly rapid disappearance of part of the plastics by sinking, accumulation on shores or degradation.

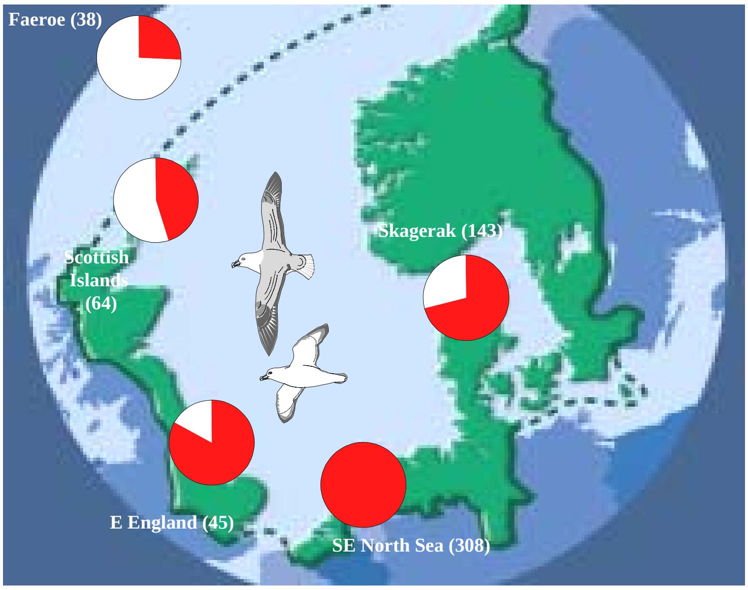


Figure 9. Regional differentiation in offshore plastic pollution measured from stomach contents of Fulmars. Geometric mean masses of plastic per region (2002-2004), are expressed as percentage (in red) of the mass in the maximum pollution region (SE North Sea) (cf Table 8).

4.3 Exploring details in North Sea data: patterns and sources

For separate locations, a number of differences suggested by geometric mean masses could not be shown to be statistically significant. Examples of these are the difference between the Shetland and Orkney Islands, the difference between southeast England and the nearby Channel, the gradual decrease of plastics from the Channel towards Denmark, and differences within the Skagerak area (Fig. 10). Lack of significance does not mean that those issues should be ignored, but that larger samples are needed to further explore the suggestions from the current data. A tentative discussion is given here to stimulate such further investigations.

Several elements in Figure 10 suggest a correlation between marine litter (plastic) levels and intensity of shipping as shown in Figure 11. Peak levels are observed in the French-English Channel followed by a gradual decrease plastic abundance along Belgium, the Netherlands and Germany towards Denmark. Also fitting the shipping pattern is a fairly sharp drop in plastic abundance near the English Norfolk coast, not far from the Channel but away from the major ship routes. Unexplained and not fitting the described pattern is the fact that Fulmars from the Lista Peninsula in Norway have a higher geometric mean mass of plastics than birds from Skagen in Denmark (not significant).

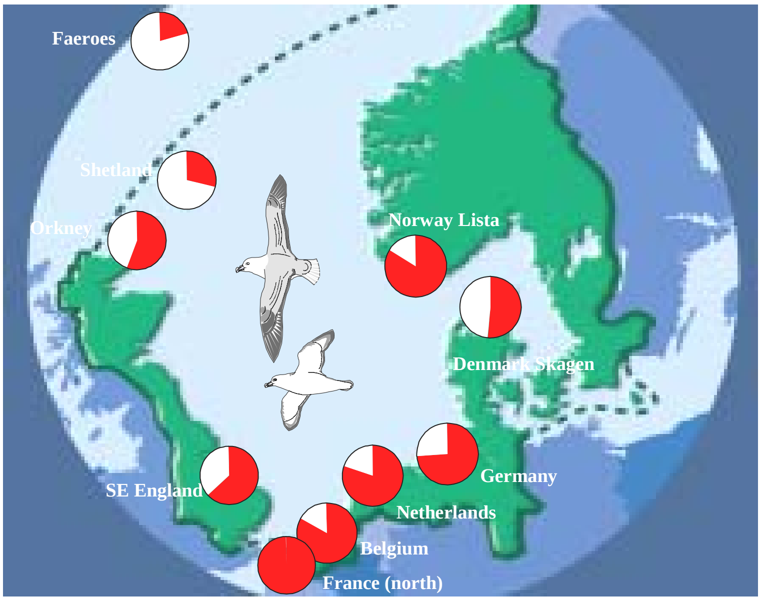


Figure 10. Location differences in offshore plastic pollution measured from stomach contents of Fulmars. Geometric mean masses of plastic per location (2002-2004) are expressed as the percentage (in red) of the mass in the maximum pollution area (French Channel) (cf Table 5). Data for NE England and Sweden omitted because of inadequate sample size.

It may be argued that these patterns could also reflect levels of coastal activity and riverine inflow from landbased sources. In our view peak levels in France do not fit that option, and there are more circumstantial data pointing towards shipping.

First consider the remarkable difference in plastic loads found in Fulmars from the Shetland and Orkney Islands. Geometric mean mass of plastics in Shetland Fulmars (0.040g) is only half that around the nearby Orkneys (0.076g) There are no major differences in population density or industrial activity on the islands that would suggest differences come from landbased litter sources. However, when details of shipping maps (Fig. 12) are considered, the immediate surroundings of Shetland prove to be much less used by ships than Orkney waters. Calculations by MARIN indicate that ship density around Shetland (2 ships per 8x8km grid-cell), is only half that around Orkney (4 ships per grid-cell). We consider that this is a strong indicator for the role of shipping in plastic levels seen in stomachs of Fulmars.

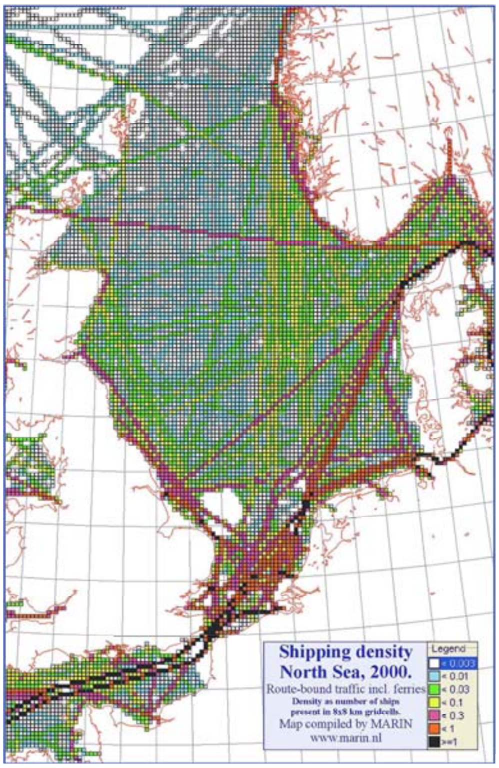


Figure 11. Shipping density North Sea, routebound traffic. Source: MARIN.

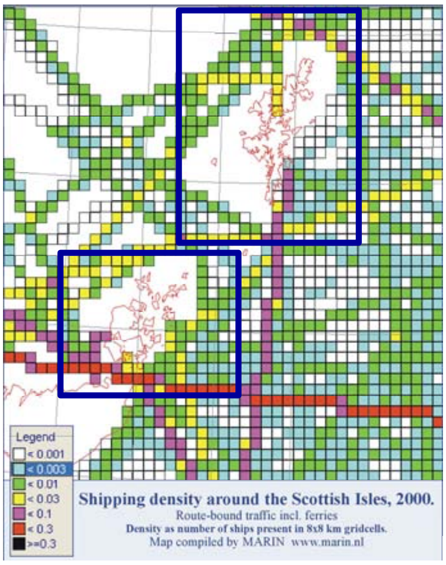


Figure 12 Shipping density around Orkney and Shetland. Source: MARIN.

Furthermore, the above patterns only considered plastic litter, and it may of use to look at other litter or plastic subcategories that could be indicative for particular sources. Our category of 'non-plastic rubbish' is dominated by galley type foodremains which can be discharged legally by ships. Considering rates of degradation, land-based sources for such food-remains must be considered unlikely. We consider presence of non-plastic rubbish in bird stomachs to be an indicator of foraging on ships wastes. Similarly the pollutant category, dominated by 'suspected' chemicals, almost certainly has its origin from tank-cleaning by ships at sea. Finally, elevated abundance of foamed plastics may be seen as indicative for immediate nearby sources at sea. Because of the extreme buoyancy of foamed plastics, wind and waves will quickly displace them, most pieces supposedly being beachwashed quickly on shores. Figure 13 explores these three indicators for the different locations. Patterns that were observed in ingested plastics correlate well to the shipping indicators. Non-plastic rubbish, pollutants and most strongly foamed plastics indicate shipping to be involved in the different plastic loads of Fulmars from the Shetland and Orkney Islands. All three indicators strongly suggest shipping to be involved in the high plastic loads of Fulmars in the French Channel area as compared to those from the Norfolk coast in SE-England. The downward trend from the Channel to Denmark is also present in the non-plastic rubbish category, and emphasized in foamed plastics. The incidence of suspected chemicals has a limited source in specific tanker operations and follows a somewhat different pattern.

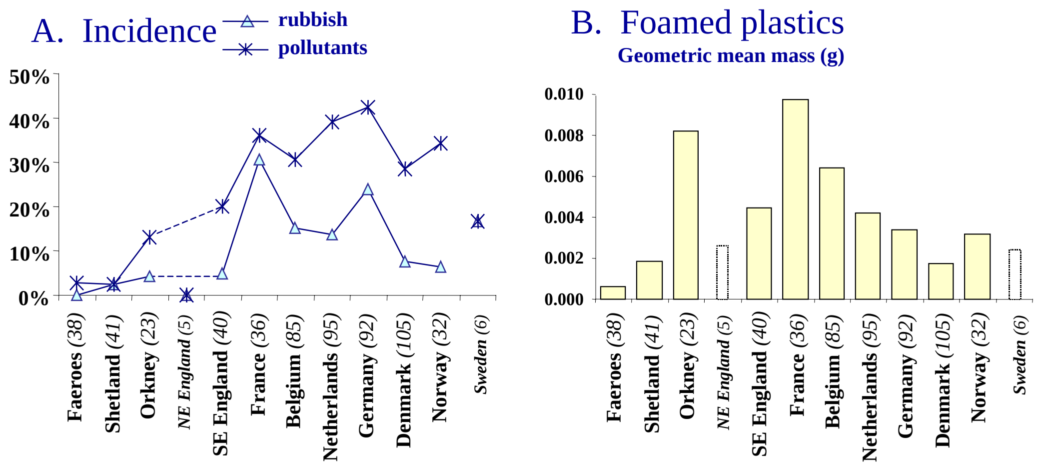


Figure 13. Shipping indicators: rubbish (mostly galley food waste), pollutants (mostly paraffine like from tank-cleaning) and foamed plastics (short availability near source). Note differences Shetland<>Orkney, SE-England<>France, and downward trend France>Denmark)

Concerning shipping as a major source of litter in Fulmar stomachs, Van Franeker *et al.* (2004) noted an increasing frequency of stomach samples in the Netherlands that contain a mud of unidentifiable food with up to many hundreds of tiny pieces of user plastic. This phenomenon at least partly explains the different patterns in number of items and mass in Figures 8b and 8c. Such tiny fragmented samples are thought to originate from foodwaste grinders as used in ship galleys. However, instead of just food, a mix of galley wastes and plastics has been chopped up. The resulting pulp, if discarded, will be attractive to seabirds. Observations of improper use of foodgrinders on cruise-liners, resulting in discharges of food-plastic mixtures, was reported on the marine mammal network (Breen, 2002).

In the above we have mainly looked at overall plastics, which are dominated by the user plastic category. Industrial plastics may be lost from ships accidentally or during cargo or cleaning operations, but their character is definitely different from the disposal of household types of waste made up of user plastics. Figure 14 looks at industrial and user plastics and user plastics separately, which reveals intriguingly different patterns. The graph for user plastics shows the Channel to Denmark decline that we have argued to be linked to shipping intensity. Industrial plastics however, show a different pattern in which an increase is seen from the Channel into the Netherlands and a subsequent decline. Such a pattern could indicate that the major rivers, and thus landbased sources have to be considered as a major source of remaining industrial plastic pollution entering the North Sea. Currently no explanation is available why Norway (and Sweden) would show elevated levels. If inflow from the Baltic would play a role, one would expect higher levels in Skagen, Denmark as well. Further work will have to shed light on the differences observed in the Skagerak.

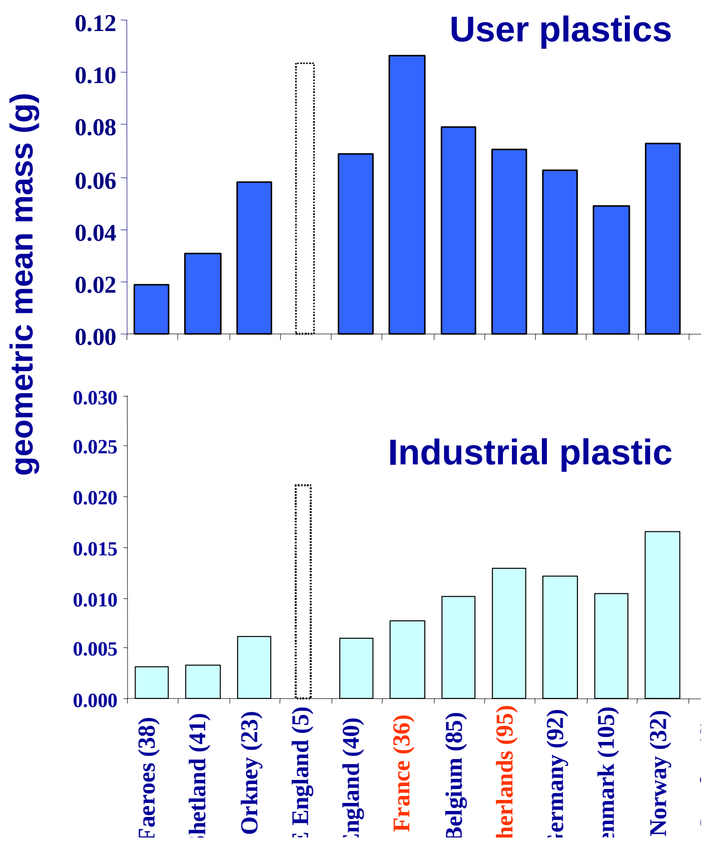


Figure 14. Different geographical patterns in abundance (geometric mean mass) of user plastics and industrial plastics suggest different main sources by which these litter categories enter the marine environment.

In conclusion, even if the differences between locations are not significant in our current data-set, a closer inspection of details and circumstantial evidence suggests that many of such differences may be realistic and often have a relation to shipping. Continued sampling on the separate locations is required to obtain further evidence. For the time being, lack of significance for separate locations necessitates usage of combined regions to substantiate the dominant pattern in litter pollution in the North Sea (Chapter 4.2). However, the data at least suggest that higher spatial resolution in Fulmar monitoring may become possible, which also assists in identifying sources and appropriate measures to reduce pollution. These prospects lead to the conclusion that it will be beneficial to continue sampling Fulmars from a wide range of locations. Our analyses also indicate that it is useful to continue recording the various subcategories of plastic and other litter as described in Chapter 2.4.

4.4 Variables potentially affecting results: the age issue

The discussion of geographical differences showed that the Fulmar as a monitoring tool for marine litter has a higher capacity for spatial resolution than we had anticipated. High sensitivity has evident advantages for monitoring purposes, but on the darker side, if one aims for optimal use of the instrument, also requires more intensive sampling. For example the variation by location in our current samples complicates further analysis of other factors that could contribute to different levels of litter in Fulmar stomachs. In the pilot study of Van Franeker & Meijboom (2002) potential factors like year, season, sex, age, origin, condition and cause of death were investigated, of which apart from 'year' only 'age' was found to be influential. Ideally, such an analysis should be repeated with the material from around the North Sea and the addition of factor 'location'. However, within the very short time frame of the Save the North Sea project, samples are insufficient and insufficiently balanced to allow such analysis. Many of the locations only have samples from two years or even just one, and differ in factors such as season, sex and age composition. Much of the 2004 samples, the bulk of our material, originated from a short period (March) of wreck conditions in the southern and eastern North Sea, and proved to concern an unusual high proportion of adult females (Van Franeker, 2004a). By separate locations, effects can not be considered because too many subsamples are lacking or of insufficient size. Combined by region, the potentially aberrant sample composition in 2004 seems to have had no major consequence on our conclusions for regional variation. In Figure 15, geometric mean masses of plastic by region (cf Fig. 7b) have been split up for separate sample years. In spite of interannual variability, the main pattern of geographical differences proves to be valid for all sampling years. So, potential unbalance in our samples leaves our main conclusions for the combined regions unaffected

The main issue in potential unbalance between samples would be age. Age differences in our regional geometric means are shown in Figure 16 and confirm findings in Van Franeker & Meijboom (2002) that younger (juvenile and immature) birds have on average more plastic in their stomach, irrespective of the area. Overall figures are usually close to those of adults suggesting no major bias from age. Results may suggest that near breeding areas, differences between adults and younger birds are stronger: non-adults near the Scottish Isles have 2.5 times the geometric mean mass of plastics of adults, where such ratio is only 1.3 to 1.4 near Skagerak and SE North Sea. This could fit one of the hypotheses on backgrounds of age-differences, namely that adults could loose plastics during colonial activity by defensive spitting and feeding chicks. The Scottish sample is too small for firm conclusions.

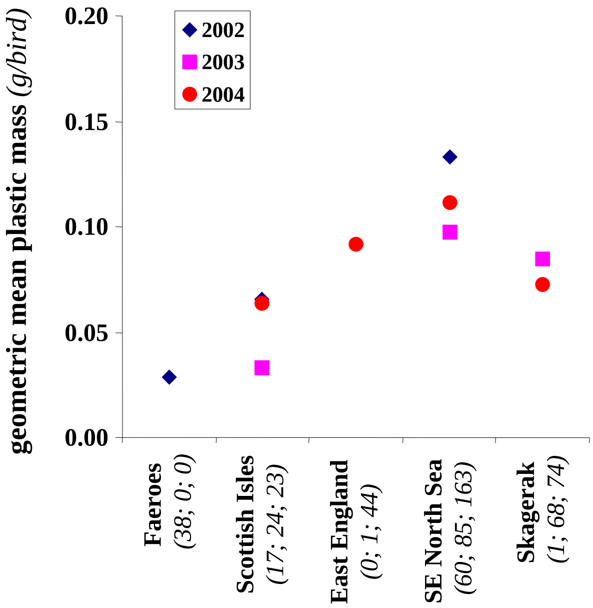


Figure 15. Interannual differences in geometric mean mass of plastics in Fulmar stomachs from different regions.

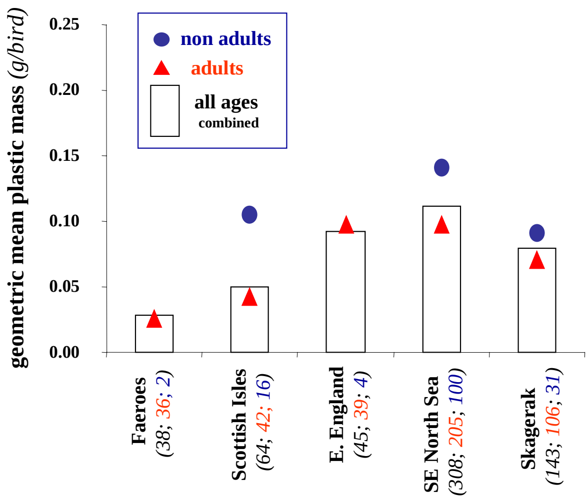


Figure 16. Age class differences in geometric mean mass of plastics in stomachs of Fulmars from different regions.

We fear that it will be extremely difficult to analyse the age issue from our North Sea samples of beachwashed birds. Individual samples will probably remain too small and too widely spread over space and time to sufficiently 'control' other variables. From the Faeroes we had a number of stomachs of birds sampled for organochlorine research programs prior to the Save the North Sea study. These samples showed remarkable differences in plastic loads depending on age. Figure 17a reveals a stepwise reduction in plastic loads in subsequent age classes. The adult sample was a combination of pre-breeding adults collected in April 1999 and post-breeding adults collected in December 2002 (Fig. 17b). The strongly different plastic load in pre-breeding versus post-breeding adults supports the hypothesis that colony attending adults may loose considerable amounts of plastics, e.g. by regurgitating them during chick-feeding. If the extreme difference seen in Figure 17b was to be confirmed by more extensive study, that would imply that sampling for monitoring purposes near breeding areas has to take seasonal variation into account as an influential variable. Away from breeding colonies, in the Dutch material, seasonal differences could not be demonstrated to influence results.

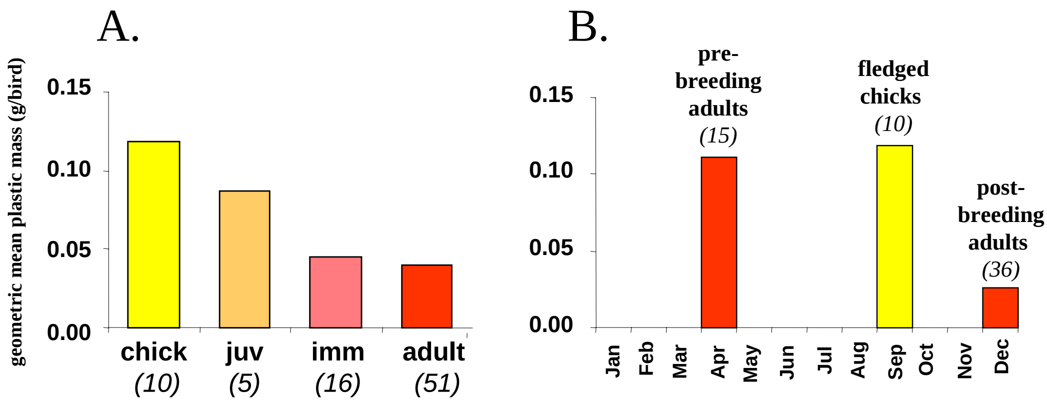


Figure 17. Faeroe Islands samples 1998-2002 illustrating differentiation in geometric mean mass of plastics in different age groups (chicks immediately after fledging; juveniles are first year birds; immatures older than one year; adults likely breeding age). Seasonal differences suggest that adults might loose plastics through regurgitation when feeding chicks.

In the Faeroes, there is a unique possibility to study the age issue in more detail. Fulmars in the Faeroes are harvested for human consumption throughout the year. Therefore in 2003 we have set up a sampling program to obtain the stomachs from such birds for every month of the year with a sample-size of about 30 to 40 stomachs of fullgrown birds per month plus chick stomachs from August and September. In addition we attempted to obtain local long-line victims. Faeroer being outside the EU Interreg definition of the North Sea, we had insufficient own funding to analyse all these stomachs, and samples have been stored frozen. However, in further studies developing the monitoring system for the OSPAR Fulmar-Litter-EcoQO, analysis of samples from the Faeroes must have high priority. Even though the age difference has been shown not to hamper the Dutch long-term monitoring, this is not necessarily the case in all areas, and age differences and their background should and can be further analysed using available collections from the Faeroes.

5 Concluding remarks and considerations for the OSPAR Fulmar-Litter-EcoQO

Ecological Quality Objectives for the North Sea were initiated by North Sea ministers during their conference in Bergen in 2002 (Anonymous, 2002). However, the implementation was delegated to OSPAR, which covers a much wider area, the whole northeastern Atlantic Ocean. Where North Sea ministers implied that the Fulmar-Litter-EcoQO should be implemented in the North Sea by the year 2004, this has now been formulated as an intended implementation in the OSPAR area by the year 2006 or 2007, depending on the outcome of 'the North Sea pilot project' (OSPAR, 2004). The 'North Sea pilot project' refers to the Save the North Sea Fulmar study and this report.

The Save the North Sea Fulmar study has 'de facto' established the monitoring network required for implementation of the Fulmar-Litter-EcoQO in the North Sea as requested by North Sea ministers in the Bergen Declaration. The combination of the long-term Dutch monitoring results and the Save the North Sea study of regional variation has shown that the Fulmar is a sensitive ecological tool to measure regional differences and time related changes in levels of marine litter in the North Sea and can assist in identifying sources of litter. Baseline-data for four regions within the North Sea, and one outside have been firmly established, and long-term trends in one of these have been documented.

As shown in this SNS report and earlier Dutch reports, abundance of litter in Fulmar stomachs can be illustrated in a number of ways, that is by incidence, by number of litter items, or by mass of litter. Incidence can be a useful metric and for example clearly illustrates the decrease in industrial plastics in the Netherlands (Fig. 8a) but looses sensitivity when virtual all individuals are affected like is the case with user plastics. Number of items is somehow the traditional metric to express plastic abundance in bird stomachs. However, particle shapes and sizes show a huge range of variation, and Dutch data show that there is a tendency that these are changing over time, obscuring trends (cf Figs 8b and 8c). In our view mass of litter is the most appropriate metric to use because it relates most directly to environmental pollution levels and its ecological impact on marine organisms. So, although it is useful to show data on incidence and number of items as associated information, we clearly advise to use mass as the decisive metric for statistical procedures describing trends, regional differences and political aims.

North Sea Ministers and OSPAR have asked to consider 'plastics' in seabird stomachs in the development of an EcoQO for marine litter. For clarity and simplicity of messages to general public, stake-holders and policy-makers we agree that the ultimate presentation of EcoQO monitoring results can show data for the combined plastic category, as has been done in many graphs in this report. However, in this report it has also been shown that it is extremely important in raw data-collection to continue to distinguish not only different types of plastics (industrial, and several types of user plastics), but also other non-plastic litter and pollutant categories. Such details are crucial to identify backgrounds of trends or regional differences and potential sources of litter which is elementary information for policy makers to achieve political aims. Although formally no part of the requested EcoQO, and usually not defined as 'marine litter', the increasing abundance of paraffine-like and suspected chemical substances on beaches and in Fulmar stomachs justifies environmental concern. The geographical pattern of this type of pollution (Fig. 7) differs somewhat from that of plastic pollution and is most prominent in Dutch to Danish waters. Cleaning operations by tankers at sea must be the source of these materials, possibly partly legal under current MARPOL Annex II regulations. Chemical characteristics of substances on beaches and in birds are largely unknown but urgently require identification.

A recurring problem for 'easy to understand' presentation of information is that data on mass of litter are not 'normally' distributed around an average value. Where many birds may contain 'moderate' quantities of plastics, the average of a sample can be strongly increased by few extremely high values. The problem is even worse for number of items. For comparative purposes, that is the statistical identification of trends over time or regional differences, one has to look at all individual values in which the effects of extremes are accounted for by e.g. logarithmic transformation or relative ranking of values. Results from such procedures (e.g. Fig. 2 and Table 4 for Dutch trends; Tables 6 and 7 for regional differences) are decisive for conclusions on trends and differences but are unattractive and not easy to understand for a wider public. To a reasonable extent (but also not perfectly) results of statistical tests can be visualized by comparisons of geometric means for samples (back-calculated from the average of ln-transformed data). For comparative purposes, used in many graphs in this report, this works fine. But in isolation, as a numerical value for a single sample, also the geometric mean does not properly express what the general public perceives as an average. In conclusion we recommend that numerical information for an EcoQO should be given as straightforward averages (arithmetic mean) of samples but that such data should be avoided for small samples and should be combined over larger regions and a number of years to reduce the effect of infrequent extremes. Statements on trends or sample differences can only be made on appropriate tests of individual values (for mass). Test results may be visualised in graphs comparing geometric means or even arithmetic means if sample sizes are made sufficiently large (e.g. 5-year averages in Fig 8c).

Putting such recommendation into practice: In the North Sea, the southeastern part (Channel exit to German Bight) is currently (2002-2004) most litter polluted with an average mass of plastic in Fulmar stomachs close to 0.4 gram (97% of birds affected; about 50 pieces per bird). This is about double the level found around the Scottish Isles (0.2g; 91%; 20 pieces) with central areas of the North Sea intermediate (Skagerak; east England) and four times the level outside the North Sea at the Faeroes (0.1g; 92%; 7 pieces). See Table 8 and Figure 9. The difference between southeastern North Sea and Scottish Isles is significant ($p=0.006$ in both T-test and Man-Whitney U test; Table 6b). Long-term trends in the Netherlands show no significant change of overall plastic in Fulmar stomachs from 1982-2003, but composition of plastic litter has strongly changed with a significant long-term decrease of industrial plastic mass ($p<0.001$) and increase of user plastic mass ($p=0.02$; linear regression on ln-transformed data; Table 4a). Long-term analysis hides the fact that user-plastics reached peak levels in the late 1990's and have shown significant decrease over the more recent 1996-2003 period ($p=0.007$ Table 4b).

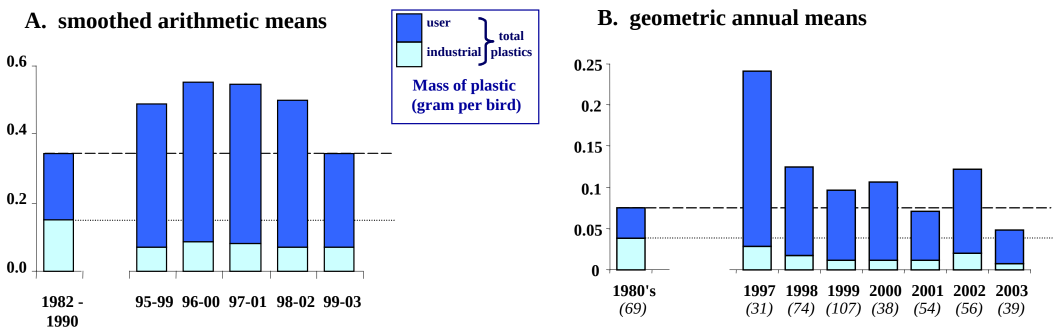


Figure 18. Different modes of showing trends and changed composition in plastic mass in stomachs of Fulmars in the Netherlands since the 1980's. Figure A shows running averages for 5 years of arithmetic means; Figure B. shows annual geometric mean mass for years of adequate sample size. Linear regression tests using all individual data give significance to changed long-term composition and decrease of user- and combined plastics since 1996.

Where we claim to have 'implemented' the Fulmar-Litter-EcoQO for the North Sea, this concerns the monitoring part and methodology for assessing trends, but not the policy target that is such a crucial element of the EcoQO approach. In an earlier stage, OSPAR's Advisory Committee on Ecosystems (ACE) worded a tentative Fulmar-Litter-EcoQO target as *'a maximum of no more than 2% of individuals having ten or more plastic particles within a sample of at least 50 Northern Fulmars'*. Initially this seemed like a somewhat complicated target definition with two mixed criteria. However, at closer consideration, this sort of target definition avoids the above discussed drawbacks associated with either arithmetic or geometric means. Defining a target in the sense of *'no more than x% of individuals exceeding an y-limit of plastic'* is insensitive for extremes, and uses simple and directly understandable units of measurement and is therefore attractive. Recently OSPAR documents further specificied an advice for the EcoQO as: "*There should be less than 2% of Northern Fulmars having ten or more plastic particles in the stomach in samples of 50-100 beach-washed fulmars found in winter (November to April) from each of fifteen areas of the North sea over a period of at least five years*" (OSPAR 2005).

Thus, for all the SNS Fulmar study locations and regions we calculated the percentage of birds that over the period 2002-2004 had more than 10 plastic items (industrial and user combined) in the stomach. Since we advise the use of mass of litter in the EcoQO, rather than the number of items, we also looked for the equivalent in terms of mass. The percentages of birds having more than 0.1 gram of plastic in the stomach proved to be very similar to those having more than 10 pieces. Both percentages are shown for all separate locations and combined regions in the bottom lines of Appendix 4a and b. We therefore propose to use the 0.1 gram plastic limit in the Fulmar-Litter-EcoQO target definition. The current situation in the

North Sea with regards to this mass limit is shown in Figure 19. In the southeastern North Sea 60% of birds currently have more than 0.1g of plastic in the stomach, compared to 44% around the Scottish Isles and 26% in our reference area, the Faeroes.

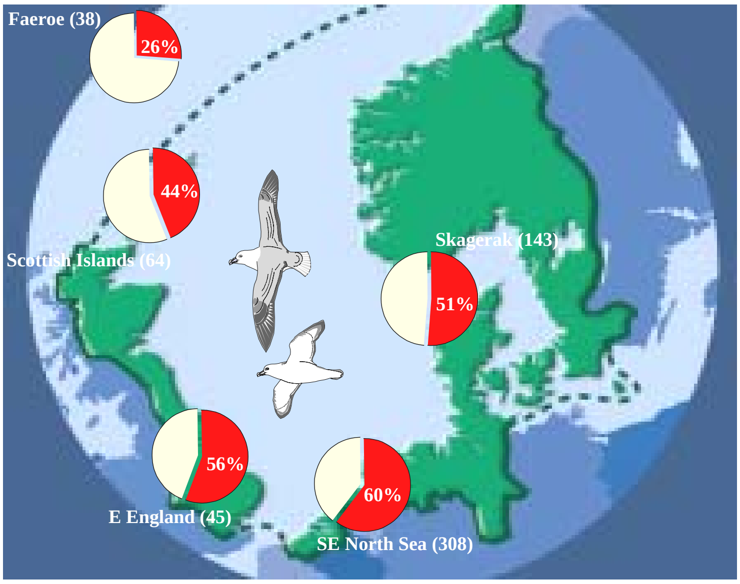


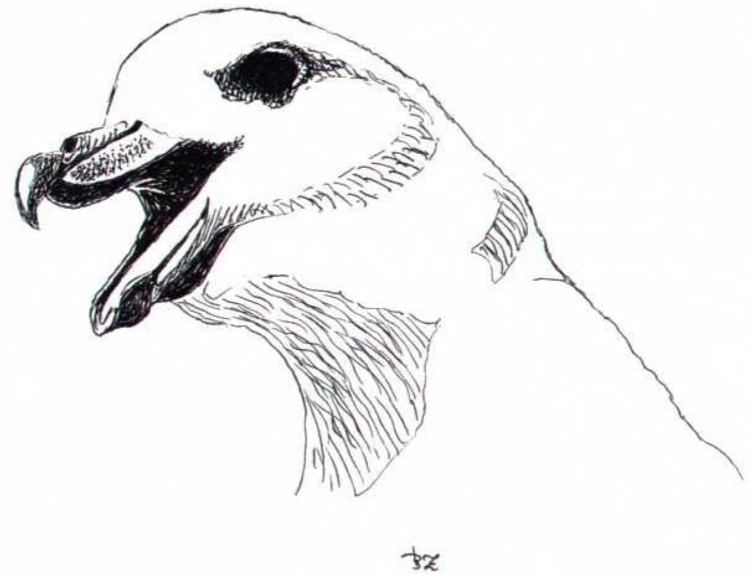
Figure 19. Regional proportions of Fulmars having more than 0.1 gram of plastic in the stomach over the years 2002-2004. Proposed mode of data presentation of compliance with EcoQO target.

When looking at this current situation a 2% upper limit for birds having more than 0.1 gram plastic in the stomach seems an extremely tough political target. Roughly, such a target would imply that the litter levels in the North Sea would have to be reduced to a level that is even 10 times lower that what we currently consider to be a relatively clean situation in the Faeroes. We do not know real background levels for marine litter in our area (litter coming in from distant sources), but it may be suspected that background pollution alone could be responsible for more than 2% of birds having more than 0.1g of plastic in the stomach. In other words, even if litter input in the European area would be successfully and completely eliminated, it is questionable whether the percentage of Fulmars with more than 0.1g of plastic in the stomach could drop to below 2%. Regional targets should not exceed what can be achieved by regional measures. We consider that a 10% upper limit for the proportion of Fulmars with more than 0.1g plastic (± half the current Faeroes level) is an ambitious but achievable EcoQO target for the North Sea. Of course the percentage to use also depends on the political time schedule by which EcoQO targets should be realized.

With regards to other elements of the EcoQO-advice in OSPAR (2005), the proposed requirement of 15 study areas within the North Sea with each annually 50 to 100 birds would be hard to realize and seems not necessary. Annual samples of around 100 birds for each of 4 to 5 North Sea regions are likely to provide adequate information on larger scale trends. At this stage there seems no need to restrict samples to the winter period (Nov-Apr), but study of our material from the Faeroes may provide further information. There can be little argument with the proposal that an EcoQO is only achieved when monotiring values remain below the target for a series of years.

In the EcoQO approach, the monitoring system is also requested to make suggestions concerning policy priorities for most efficient options to reach EcoQO targets. Various details of the Fulmar study (and others) indicate that within the North Sea region, garbage and operational wastes disposed from ships (merchant and fisheries) is one of the major sources of marine litter. Policy measures in the shipping sector, especially strict shore-based control and improved harbour-service as intended by the EU-Directive on Port Reception Facilities, may thus have high potential for improvement. Usage of waste-grinders on ships and possibly offshore platforms may be an other relevant issue. Of course this does not imply that other sources and general policies towards disposable products can be neglected

EU-Interreg IIIB funding for the Save the North Sea project has enabled a successful start to the implementation of the Fulmar-Litter-EcoQO as requested by North Sea Ministers in 2002. The research network has been established, methodology developed, and baseline data have been collected. However, sooner than expected, EU-Interreg funding has stopped after December 2004. This means that the network and continued data-collection are under immediate threat, let alone that expansion to the wider OSPAR region could be considered. Alternative funding is urgently required in order not to loose 'the momentum' that we now have in working towards a Fulmar-Litter-EcoQO in the OSPAR area.



6 Acknowledgements

Our sincere thanks have to go to all those involved in collecting dead Fulmars from beaches. In many cases these are non-paid volunteers assisting in Beached Bird Surveys primarily intended for oil pollution monitoring. In other cases birds were collected by people professionally working at beaches (biologists, wardens, beach-clean-up teams) but whose job-description definitely does not include the effort of collecting and labelling smelly bird corpses. Without such people and their supporting organisations, a project like this would be absolutely impossible. Persons and organisations most strongly involved have been listed in Appendix 1 and through them we express our admiration and deepest gratitude to all those that support the Fulmar project. In the Faeroes Maria Dam of the Food and Environmental Agency and Poul Jóhannis greatly assisted in the project. Kees Tak from MARIN kindly dedicated time to produce shipping density maps and calculations.
We are also very grateful to partners in the 'Save the North Sea' project and stake-holders in the SNS Reference Group for their support in establishing contacts, disseminating results and administrative support. From the Reference Group, Shell made a contribution partially covering the printing of the current report. Partial financial support for the Belgian studies was provided by the Management Unit of the North Sea Mathematical Models (MUMM). Dutch Fulmar studies have received financial support from the Netherlands Ministry of Transport, Public Works and Water Management (VenW), and the North Sea study would not have been possible without the financial support from the EU Interreg IIIB North Sea program to the Save the North Sea project.

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Appendix 2 Standard form fulmar dissections

Species | Collection number ... - ... - ... | Dissected by:

Find-Date (dd-mon-yyyy) ... - ... - ... | Finder:

country | location

Corpse - condition
freshness: FFF FF F O OO OOO | oil % ... % | entanglement ? no yes | *notes*
completeness: CC C I II | other ext fouling % ... % | fractures/wounds? no yes

Plumage
colour-phase: LL L D DD / W Coloured
primary moult L (p10 *to* p1) | *or* no yes | *score*
primary moult R (p10 *to* p1) | *or* no yes
Tail moult ….. - ….. | *or* no yes
Secondary moult no yes | Body feather moult *external* no yes | Body feather moult *internal* no yes | Incubation patch present? no yes

Measurements
CulmenLength . | BillDepth . | HeadLength | TarsusLength .
WingLength | WeighT - =

Condition breast muscle 0 1 2 3 | Subcutaneous fat 0 1 2 3 | Intestinal fat 0 1 2 3 | Overall Condition INDEX

sex *(circle male or female)*
MALE testis colour *(descr)* | FEMALE oviduct code 1 2 3 4 | male sex INDEX
length x width *(mm)* x | max follicle *(mm)* . | female sex INDEX

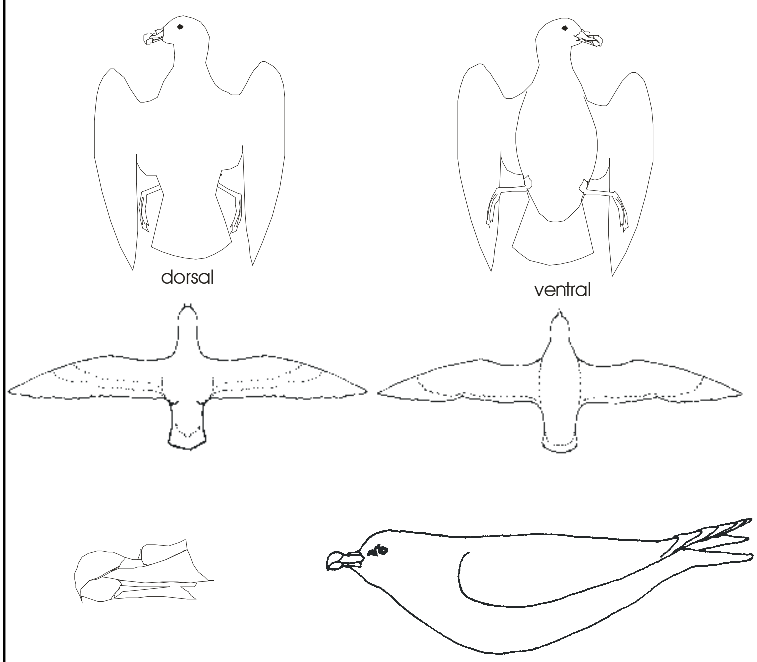
bursa fabricius present? no yes | bursa length x width *(mm)* x | =bursa INDEX

organ health stomach 0 1 2 3 | liver 0 1 2 3 | gut 0 1 2 3 | kidney 0 1 2 3 | lung 0 1 2 3

Notes/conclusions on likely cause of death

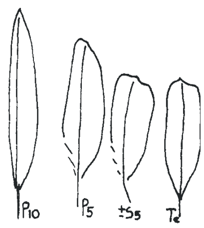
parts collected:

notes



Collection nr.

Notes on colouration, fouling, injuries etc..



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Appendix 3 Standard form stomach analysis

STOMACH contents form			Bird/sample nr =		
nr of stomach ulcers =		DRW =			
worm infected =		After sieving; before rinsing (only if more than few remains)			
		total for both stomachs (proventriculus and gizzard)			sample
PLASTIC		n item	g airdry	notes	number
IND	pellets				
?	probab ind?				
USER	sheat				
	thread				
	foam				
	fragments				
	other				
OTHER RUBBISH		n item	g airdry	notes	sample
	paper				
	kitchenfood				
	other user				
	FISHHOOK				
INDUS/CHEM WASTE		n item	g airdry	notes	sample
	slag/coal				
	oil/tar				
	paraf/chem				
	featherlump				
NATURAL FOOD		n indv	g DRW	notes (*weigh subcat's only if substantial*)	sample
	FISH			oto: lens: bones: whole	
	SQUID			jaw: eyes: shield: whole	
	CRUSTACEAN				
	JELLY TYPE				
	BIRD/MAMMAL				
	other				
	other				
	other				
NATURAL NON FOOD		n	g airdry	notes	sample
	plant				
	seaweed				
	pumice				
	stones				
	other				
	feathers normal				
	worms				

NOTES

Appendix 4a Sample details by location

SNS-FULMAR 2002-2004 Sample and stomach content details by location

	Faeroes	Shetland	Orkney	Northeast England	Southeast England	France (north)	Belgium	Nether-lands	Germany	Denmark Skagen	Norway Lista	Sweden Sotenes
sample size	***38***	***41***	***23***	***5***	***40***	***36***	***85***	***95***	***92***	***105***	***32***	***6***
proportion adult birds	95%	77%	68%	40%	97%	92%	76%	55%	62%	79%	74%	60%
proportion male birds		39%	57%	40%	10%	3%	16%	37%	26%	41%	50%	50%
proportion colourphase LL		85%	96%	80%	93%	89%	93%	78%	87%	95%	97%	100%
proportion birds having oil		7%	9%	0%	0%	0%	11%	13%	8%	9%	19%	0%

ALL PLASTICS (industrial and user combined)

	Faeroes	Shetland	Orkney	Northeast England	Southeast England	France (north)	Belgium	Nether-lands	Germany	Denmark Skagen	Norway Lista	Sweden Sotenes
incidence	**92%**	**88%**	**96%**	**100%**	**93%**	**100%**	**98%**	**97%**	**95%**	**94%**	**97%**	**83%**
nr of pieces per bird	**7**	**15**	**28**	**13**	**30**	**58**	**74**	**42**	**39**	**39**	**60**	**48**
mass per bird (g)	**0.09**	**0.18**	**0.28**	**0.18**	**0.21**	**0.25**	**0.37**	**0.36**	**0.35**	**0.38**	**0.39**	**0.63**
maximum mass observed	**0.5**	**1.7**	**1.2**	**0.3**	**1.1**	**0.9**	**4.3**	**11.1**	**4.3**	**20.6**	**1.8**	**3.0**
geometric mean mass	*0.0287*	*0.0398*	*0.0758*	*0.1562*	*0.0861*	*0.1375*	*0.1140*	*0.1100*	*0.1013*	*0.0706*	*0.1153*	*0.0712*

INDUSTRIAL PLASTIC

	Faeroes	Shetland	Orkney	Northeast England	Southeast England	France (north)	Belgium	Nether-lands	Germany	Denmark Skagen	Norway Lista	Sweden Sotenes
incidence	39%	37%	52%	80%	45%	58%	60%	61%	63%	61%	66%	67%
nr of pieces per bird	1	1	2	2	2	3	4	4	3	3	6	19
mass per bird (g)	0.02	0.03	0.05	0.06	0.05	0.04	0.07	0.07	0.06	0.05	0.10	0.44
maximum mass observed	0.1	0.4	0.5	0.2	0.3	0.3	1.3	0.5	0.5	0.4	0.6	2.4
geometric mean mass	*0.0031*	*0.0034*	*0.0062*	*0.0212*	*0.0061*	*0.0077*	*0.0101*	*0.0129*	*0.0121*	*0.0105*	*0.0165*	*0.0319*

USER PLASTICS

	Faeroes	Shetland	Orkney	Northeast England	Southeast England	France (north)	Belgium	Nether-lands	Germany	Denmark Skagen	Norway Lista	Sweden Sotenes
incidence	84%	88%	96%	100%	93%	100%	98%	95%	93%	94%	97%	83%
nr of pieces per bird	7	13	26	11	28	54	70	39	36	37	54	29
mass per bird	0.07	0.15	0.23	0.12	0.16	0.21	0.30	0.29	0.29	0.32	0.29	0.18
maximum mass observed	0.4	1.7	1.1	0.2	1.0	0.7	3.4	10.7	4.3	20.6	1.6	0.6
geometric mean mass	*0.0185*	*0.0309*	*0.0578*	*0.1037*	*0.0691*	*0.1061*	*0.0792*	*0.0707*	*0.0626*	*0.0487*	*0.0727*	*0.0440*

NON PLASTIC RUBBISH (paper, foil, foodwastes, wood etc)

	Faeroes	Shetland	Orkney	Northeast England	Southeast England	France (north)	Belgium	Nether-lands	Germany	Denmark Skagen	Norway Lista	Sweden Sotenes
incidence	0%	2%	4%	0%	5%	31%	15%	14%	24%	8%	6%	17%
nr of pieces per bird	0.0	0.0	1.0	0.0	1.2	0.6	0.8	0.4	2.7	0.5	0.2	0.2
mass per bird (g)	0.000	0.000	0.001	0.000	0.000	0.016	0.052	0.066	0.063	0.053	0.114	0.034
maximum mass observed	0.00	0.02	0.03	0.00	0.00	0.22	3.93	2.45	1.54	4.10	3.42	0.21
geometric mean mass	*0.0000*	*0.0001*	*0.0002*	*0.0000*	*0.0000*	*0.0016*	*0.0006*	*0.0009*	*0.0017*	*0.0004*	*0.0005*	*0.0014*

OTHER POLLUTANTS (mainly suspected chemicals (see below) slags, tar, fouled feathers)

	Faeroes	Shetland	Orkney	Northeast England	Southeast England	France (north)	Belgium	Nether-lands	Germany	Denmark Skagen	Norway Lista	Sweden Sotenes
incidence	3%	2%	13%	0%	20%	36%	31%	39%	42%	29%	34%	17%
nr of pieces per bird	0.0	0.0	0.1	0.0	2.0	3.9	1.8	2.4	9.0	2.1	4.5	12.5
mass per bird (g)	0.000	0.000	0.073	0.000	0.068	0.022	0.151	1.015	0.647	0.215	0.033	1.077
maximum mass observed	0.01	0.00	1.25	0.00	2.04	0.50	6.00	68.18	15.00	7.00	0.33	6.46
geometric mean mass	*0.0001*	*0.0000*	*0.0008*	*0.0000*	*0.0010*	*0.0013*	*0.0018*	*0.0056*	*0.0076*	*0.0017*	*0.0031*	*0.0033*

SUSPECTED CHEMICALS (mainly paraffine like substances)

	Faeroes	Shetland	Orkney	Northeast England	Southeast England	France (north)	Belgium	Nether-lands	Germany	Denmark Skagen	Norway Lista	Sweden Sotenes
incidence	3%	2%	9%	0%	13%	28%	25%	22%	34%	23%	28%	17%
nr of pieces per bird	0.0	0.0	0.1	0.0	0.4	3.5	1.5	2.1	8.7	2.0	3.2	12.5
mass per bird (g)	0.000	0.000	0.054	0.000	0.026	0.007	0.101	0.817	0.566	0.214	0.027	1.077
maximum mass observed	0.01	0.00	1.25	0.00	1.00	0.11	6.00	65.00	15.00	7.00	0.33	6.46
geometric mean mass	*0.0001*	*0.0000*	*0.0004*	*0.0000*	*0.0004*	*0.0008*	*0.0010*	*0.0017*	*0.0038*	*0.0014*	*0.0020*	*0.0033*

Fulmar - Litter - EcoQO (plastic) "compliance"

	Faeroes	Shetland	Orkney	Northeast England	Southeast England	France (north)	Belgium	Nether-lands	Germany	Denmark Skagen	Norway Lista	Sweden Sotenes
% above 10 piece criterion	**21%**	**41%**	**43%**	**60%**	**53%**	**61%**	**58%**	**60%**	**52%**	**54%**	**59%**	**67%**
% above 0.1g criterion	**26%**	**41%**	**48%**	**60%**	**55%**	**58%**	**56%**	**62%**	**62%**	**49%**	**56%**	**67%**

Appendix 4b Sample details for combined regions

SNS-FULMAR 2002-2004 Sample and stomach content details by region

	Faeroes	Scottish Isles	East England	Souteast North Sea	Skagerak	NORTH SEA WITHOUT FAEROES
sample size	*38*	*64*	*45*	*308*	*143*	*560*
proportion adult birds	95%	74%	91%	67%	77%	72%
proportion male birds		45%	13%	24%	43%	31%
proportion colourphase LL		89%	91%	86%	96%	89%
proportion birds having oil		8%	0%	9%	10%	9%
ALL PLASTICS (industrial and user combined)						
incidence	**92%**	**91%**	**93%**	**97%**	**94%**	**95%**
nr of pieces per bird	**7**	**20**	**28**	**52**	**44**	**44**
mass per bird (g)	**0.09**	**0.22**	**0.21**	**0.35**	**0.39**	**0.33**
maximum mass observed	**0.5**	**1.7**	**1.1**	**11.1**	**20.6**	**20.6**
geometric mean mass	*0.0287*	*0.0502*	*0.0920*	*0.1113*	*0.0789*	*0.0917*
INDUSTRIAL PLASTIC						
incidence	39%	42%	49%	61%	62%	58%
nr of pieces per bird	1	2	2	4	4	3
mass per bird (g)	0.02	0.04	0.05	0.06	0.08	0.06
maximum mass observed	0.1	0.5	0.3	1.3	2.4	2.4
geometric mean mass	*0.0031*	*0.0042*	*0.0070*	*0.0111*	*0.0122*	*0.0099*
USER PLASTICS						
incidence	84%	91%	93%	96%	94%	95%
nr of pieces per bird	7	18	26	48	40	41
mass per bird	0.07	0.18	0.16	0.29	0.31	0.27
maximum mass observed	0.4	1.7	1.0	10.7	20.6	20.6
geometric mean mass	*0.0185*	*0.0387*	*0.0722*	*0.0738*	*0.0531*	*0.0630*
NON PLASTIC RUBBISH (paper, foil, foodwastes, wood etc)						
incidence	0%	3%	4%	19%	8%	13%
nr of pieces per bird	0.0	0.4	1.0	1.2	0.4	0.9
mass per bird (g)	0.000	0.001	0.000	0.055	0.066	0.047
maximum mass observed	0.00	0.03	0.00	3.93	4.10	4.10
geometric mean mass	*0.0000*	*0.0001*	*0.0000*	*0.0011*	*0.0005*	*0.0007*
OTHER POLLUTANTS (mainly suspected chemicals (see below) slags, tar, fouled feathers)						
incidence	3%	6%	18%	37%	29%	30%
nr of pieces per bird	0.0	0.1	1.8	4.4	3.1	3.3
mass per bird (g)	0.000	0.026	0.060	0.551	0.211	0.365
maximum mass observed	0.01	1.25	2.04	68.18	7.00	68.18
geometric mean mass	*0.0001*	*0.0002*	*0.0008*	*0.0040*	*0.0020*	*0.0025*
SUSPECTED CHEMICALS (mainly paraffine like substances)						
incidence	3%	5%	11%	27%	24%	22%
nr of pieces per bird	0.0	0.0	0.4	4.0	2.7	2.9
mass per bird (g)	0.000	0.020	0.023	0.450	0.209	0.305
maximum mass observed	0.01	1.25	1.00	65.00	7.00	65.00
geometric mean mass	*0.0001*	*0.0001*	*0.0003*	*0.0018*	*0.0016*	*0.0013*
Fulmar - Litter - EcoQO (plastic) "compliance"						
% above 10 piece criterion	**21%**	**42%**	**53%**	**57%**	**56%**	**55%**
% above 0.1g criterion	**26%**	**44%**	**56%**	**60%**	**51%**	**56%**