Fulmar Litter EcoQO monitoring along Dutch and North Sea coasts

in relation to EU Directive 2000/59/EC on Port Reception Facilities: results to 2009.

J.A. van Franeker & the SNS Fulmar Study Group

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Cover page photo:

An Arctic, dark colour-phase Fulmar on the beach of Texel in January 2009. During the first weeks of 2009 a sudden influx and mortality ("wreck") of Fulmars from northern areas occurred in the southern North Sea.

i. Summary Report

Fulmar Litter EcoQO monitoring along Dutch and North Sea coasts in relation to EU Directive 2000/59/EC on Port Reception Facilities: results to 2009.

Operational and cargo related wastes from ships are an important source of litter in the marine environment in the southern North Sea and cause serious economic and ecological damage. Inadequacies in the ship to shore waste delivery procedures are considered a major factor in illegal discharges. The European Union therefore addressed the problem with the Directive on Port Reception Facilities (Directive 2000/59/EC). Obligatory waste delivery to shore and indirect financing of the costs are key-elements of the Directive to stimulate and enforce proper disposal of ship-waste in harbours. Monitoring the effect of the EU Directive is required.

A long term marine litter monitoring program based on plastic abundance in stomachs of a seabird, the Northern Fulmar exists in the Netherlands. Fulmars are purely oceanic foragers that ingest all sorts of litter from the sea surface and do not regurgitate poorly degradable diet components, but slowly wear these down in the stomach. Accumulated plastic items in stomachs of beached Fulmars thus integrate litter levels encountered over a number of weeks in a particular marine area. The Dutch monitoring approach using fulmars was further developed for international implementation by OSPAR as one of its 'Ecological Quality Objectives (EcoQO's)' for the North Sea (OSPAR 2008, 2010a,b). This approach is now also considered as one of the indicators for 'Good Environmental Status' in the Marine Strategy Framework Directive (EC 2008, 2010).

In the Netherlands, the Ministry of Infrastructure and the Environment commissions regular updates of Dutch data in the Fulmar-Litter monitoring database maintained by IMARES. North Sea wide EcoQO monitoring was started in 2002 in the 'Save the North Sea' project supported by the EU Interreg IIIB program, and was continued to 2007 using CSR awards from the NYK Group Europe Ltd. After 2007, international funding to continue the analyses for the North Sea OSPAR EcoQO has proven to be complex. Fortunately, the current DGLM contract assists to fill the substantial gaps in international funding. This IMARES report thus, in addition to Dutch monitoring results, also provides a North Sea wide EcoQO update up to 2009. Appendices provide details for countries that did arrange subcontracts for their national data.

MONITORING DATA FOR THE NETHERLANDS

The year 2009

Fulmars were scarce in 2008, but in the first week of January 2009 a strong influx of fulmars occurred in the southern North Sea, immediately followed by a considerable number of dead birds on beaches. In this mass mortality ("wreck"), dark plumage colour of nearly half of the birds indicated an arctic origin. In the Netherlands, overall 78 Fulmars were collected in 2009, of which 68 had intact stomachs. The majority, 55 birds (46 stomachs) originated from the wreck in January, the remaining 24 corpses (22 stomachs) were found in other months. Among the 68 stomachs, 66 contained plastic (97% incidence), with an average of 19.3 plastic items and mass of 0.22 gram plastic per bird. Industrial plastics represented a minority (less than 2 'pellets' per bird, 0.04g) compared to discarded user plastics (over 17 items and 0.18g per bird) (Tables 1a and 2a). These 2009 figures suggest substantial lower abundance of plastics than in previous years, but a considerable part of this sudden drop is an artefact linked to the January influx of arctic birds. The almost instant mortality must have prevented that their stomach contents became representative for foraging in the Dutch continental shelf area. Indeed, birds collected in January 2009 had an unusual low abundance of plastic in the stomach, with plastic mass of 0.15g compared to a more 'usual' 0.36g for the birds collected in the remainder of the year (Table 2b). However, considering the large proportion of young birds (77%) in the latter sample, also the 0.36g average plastic mass may be characterized as relatively clean (Fig. 3) because young birds have normally higher loads of plastic.

Current levels for the Netherlands (2005-2009)

Because of occasional years of low sample size (e.g. 2008) and incidental variability (e.g. 2009), it is strongly recommended to describe the 'current pollution level' on the basis of average stomach contents over the most recent 5 years, which is also a standard element in the description of the OSPAR EcoQO (see below) Over the 2005-2009 period, in a sample of 227 Northern Fulmars from the Dutch coast, plastic incidence was 95% with an average ± se number of 27.3±2.5 pieces, and average mass of 0.29±0.03 gram (details in Table 1b). This represents a slight improvement in comparison to the earlier 5-year period (2004-2008) (Table 3).

Trends in the Netherlands

Analyses of trends focus on the mass of plastic, rather than on incidence or number of particles, and make a distinction between:

- 'long-term trend' which calculates the trend over all years in the dataset (now 1979-2009)
- 'recent trend' defined as trend over the past 10 years (now: 2000-2009)

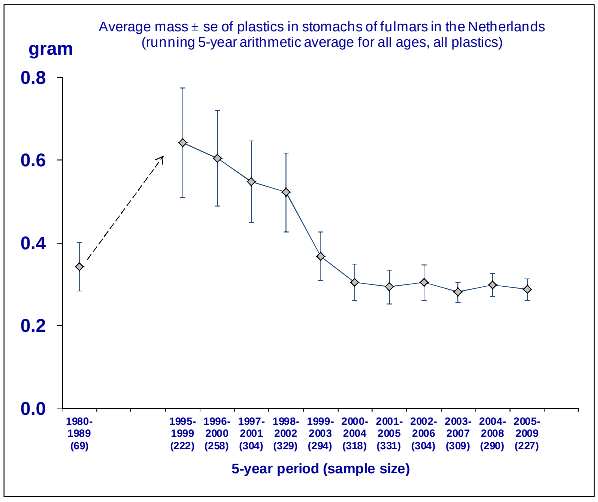
Changes are visualised in Fig. i on the basis of an overall average for the 1980's plus running 5-year averages for plastic mass in stomachs of Fulmars from the Dutch coast since the mid-1990s. Statistical tests for significance of trends are based on linear regressions of ln-transformed data for the mass of plastics against year of collection in individual stomachs (Table 4).

Long term trend 1979-2009

In spite of evident strong changes in Fig. i, the 'all plastics' category shows no clear long term linear trend (Table 4A) because plastics initially strongly increased but subsequently decreased to about the initial level. User plastics were mainly responsible for this. Industrial plastics on the other hand have strongly decreased since the early 1980s, resulting in a highly significant long-term reduction ($p<0.001$). As a consequence of this mix of trends, the composition of plastic litter has strongly changed since the early 1980s, with nowadays a reduced proportion of industrial plastics (from about 50% to circa 20% of total mass) and an increased mass of user plastics from discarded waste (Tables 1 and 2). Decreases in industrial plastics have also been observed in other parts of the world.

Recent 10-year trend 2000-2009

Until 2006, regression analyses for 10-year trends showed significant decreases in litter since the mid 1990's, mainly due to decreases in user plastics (Fig. i). However, in the analyses for later periods changes were no longer significant, because changes in both industrial and user plastics have been relatively minor after the turn of the century. Fortunately the 2000-2009 analyses for trends do suggest continued decreases for both user and industrial plastic in Dutch Fulmars (signs of t values in table 4B all negative) but at an extremely slow and statistically insignificant speed.



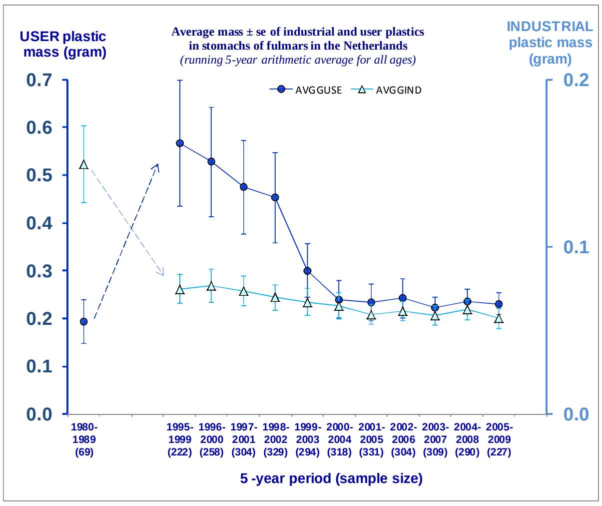


Figure i ***Trends in plastic mass in stomachs of Fulmars from the Netherlands 1980s-2009.*** *The figure on the left shows data for all plastics combined; the figure on the right splits these data into user plastic (circles, left y-axis) and industrial plastic (triangles, right y-axis). For higher resolution see Figures 1 and 2 in the main report. Data are shown by averages ± standard errors for mass in a single datapoint for the 1980s and running 5 year averages after 1995 (i.e. data points shift one year ahead at a time).*

Dutch data in terms of the OSPAR EcoQO metric

The Dutch studies have led to the development of the OSPAR Ecological Quality Objective for marine litter based on the amount of plastic in Fulmar stomachs (OSPAR 2008, 2010b). This approach is also considered as one of the indicators for 'Good Environmental Status' in the Marine Strategy Framework Directive (EC 2008, 2010). In the EcoQO approach, the above data are viewed in a slightly different manner, that is they focus on 'the percentage of birds exceeding a critical value of plastic in the stomach'. The OSPAR Ecological Quality Objective for marine litter currently formulates its target for acceptable ecological quality in the North Sea as:

> *"There should be less than 10% of Northern Fulmars having 0.1 gram or more plastic in the stomach in samples of 50-100 beached fulmars from each of 5 different regions of the North Sea over a period of at least 5 years".*

This target means that in Fig. *ii*, the bars should be reduced to below the red line. Calculated over 2005-2009, 58% of 227 fulmars beached in the Netherlands currently exceeds the critical level of 0.1 g of plastic in the stomach (Table 2a; Fig. *ii).* The low 45% figure for just year 2009 (Table 2a) is biased because of the wreck of arctic birds in early January. Clearly any of these figures is still far above OSPARs target of 10%, but data do present an improvement in comparison to the earlier period.

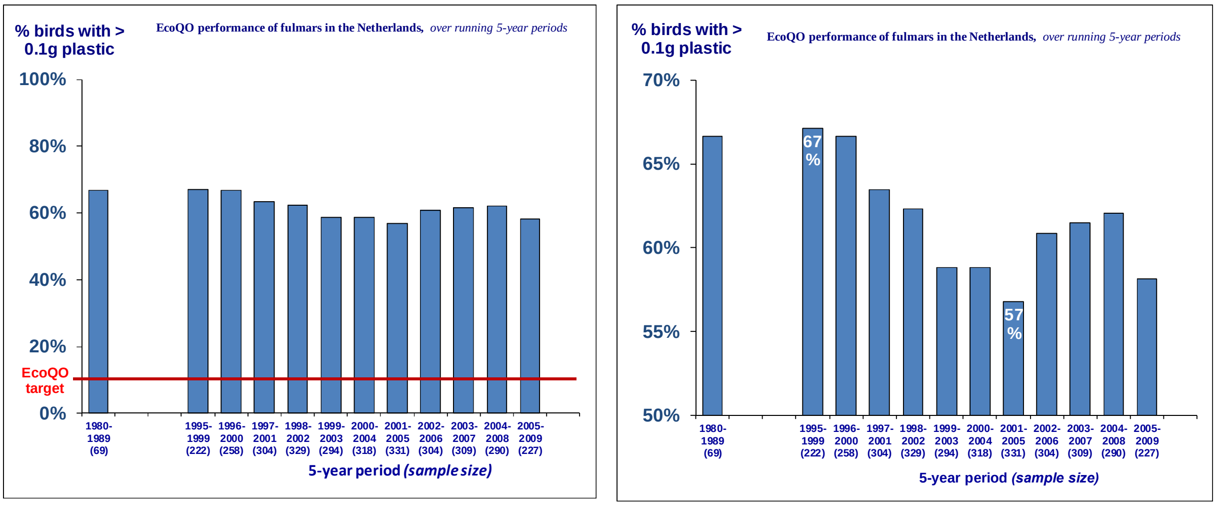


Figure ii ***EcoQO performance in the Netherlands 1980s-2009*** *– Trend in percentage of stomachs of beached Fulmars in the Netherlands containing more than 0.1 gram plastic (running average over 5 year periods, each bar shifting one year). The graph on the left shows the full 100% y-axis, with the EcoQO target shown; the graph on the right shows the same data but with the Y-axis restricted to the 50 to 70% range to show details of changes.*

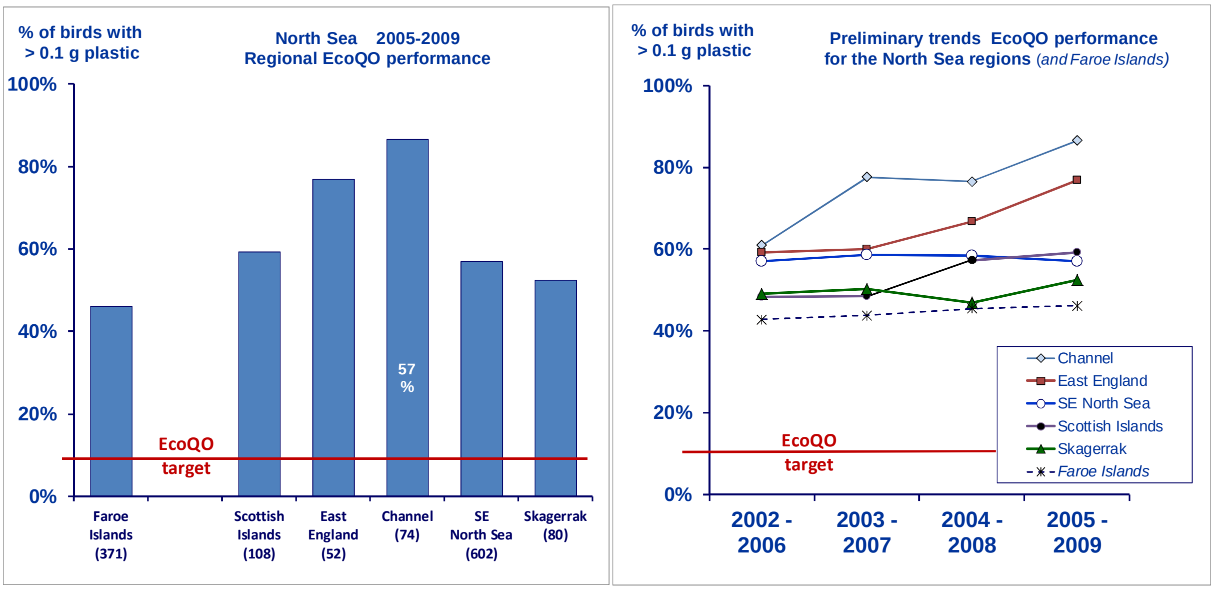


Figure iii ***EcoQO performance in North Sea regions 2005-2009 and preliminary trends.*** *Trend shown by connecting running average 5 year data points.*

MONITORING DATA FOR THE NORTH SEA

Fulmar study areas in the North Sea are grouped into 5 regions, that is the Scottish Islands (Shetland and Orkney), East England (north- and southeast), Channel (Normandy and Pas de Calais), South-East North Sea (Belgium, Netherlands and Germany), and the Skagerrak (Skagen Denmark, Lista Norway and Swedish west coast).
During 2005-2009 and calculated over the whole North Sea, 95% of Fulmars had plastic in the stomach and 60% exceeded the 0.1g EcoQO level, and the average stomach content contained 30 particles of plastic, weighing 0.33g (details in Table 5).
Underlying this average is a consistent regional pattern, in which highest plastic abundance is seen in Fulmars from the Channel, with decreasing levels further to the north both along western and eastern shores of the North Sea. Regional EcoQO percentages for 2005-2009 range from 53% to 80%, all far above the OSPAR target of 10% maximum (Fig. *iii;* Table 5). Even in the less polluted reference area, the Faroe Islands, EcoQO performance 2005-2009 was 46%. In the North Atlantic, only the Canadian arctic approaches the OSPAR target for acceptable environmental quality.
Time series for other locations than the Netherlands are still too short to properly evaluate trends. However, an initial data survey (Fig. iii, right graph) suggests that where pollution in the Southeast North Sea has remained about constant since 2002 most other regions tend to show increasing litter levels. The trend in the SE North Sea is mainly driven by relatively low pollution levels in Belgium and the Netherlands. None of the trends is significant when for example age related differences are taken into account. Continued monitoring will be needed to validate results of this initial survey.

Monitoring data in relation to shipping policy

The residual currents in the European Atlantic are northwards through the Channel and around the UK mainland into the North Sea. The large difference in pollution between the Channel and Scottish Islands shows that a large proportion of North Sea marine litter is of local origin. If debris floating into Europe with Gulfstream waters was to blame, pollution to the north and south of UK would be much more similar. In addition, high levels of litter in Normandy, well before inflow of major river systems, suggest that that litter in the North Sea is linked to sea-based activities, in particular shipping, rather than to riverine inputs. Elevated levels of debris in stomachs of Fulmars around the Orkneys as compared to those from the Shetlands indicate shipping to be an important local source of marine litter, because shipping density around Orkney is about double that around the Shetlands. A large detailed beach study on Texel, the Netherlands, in 2005 confirmed both conclusions i.e. that most debris has a local origin and is mainly linked to merchant shipping and fisheries (Van Franeker 2005).
In spite of this evident role of shipping, the implementation of the EU Directive 2000/59/EC on Port Reception Facilities has not resulted in significant improvement in Fulmar EcoQO performance in the Dutch time series (Fig. ii) or the preliminary trends for other North Sea locations (Fig. iii). Improvement in EcoQO performance mainly occurred in the late 1990s, prior to, not after implementation of the Directive. In recent years, the comparatively stable EcoQO performance of fulmars off the Belgian and Dutch coasts and a continuing decline in foamed plastics might be weak signals that in this area the intentional waste disposal by ships is somewhat decreasing. Thus, when viewed in the light of increased shipping and increased proportions of plastics in waste, the EC Directive on Port Reception Facilities may have assisted in preventing increases in marine debris, but has not resulted in the environmental improvement that it intended. If environmental improvement remains the goal, additional action will be needed.

CONCLUSIONS

1. North Sea governments aim at an Ecological Quality Objective (EcoQO) in which less than 10% of Fulmars exceed a critical level of 0.1 gram plastic in the stomach.
2. In the Netherlands, 58% of Fulmars currently exceed the 0.1 gram level (*227 fulmars 2005-2009: 95% contained plastic with on average 27 particles weighing 0.29g).*
3. Long term data for the Netherlands show a sharp increase of marine plastic litter from the early 1980s to the mid-1990s, followed by a similar sharp decline but stabilization and lack of significant improvement after the turn of the century.
4. The composition of ingested plastic has changed significantly since the 1980s with a strongly reduced proportion of industrial plastic and increased proportion of consumer waste.
5. Averaged over the whole North Sea, 60% of Fulmars exceed the 0.1g EcoQO level *(916 fulmars 2005-2009: 95% contained plastic with on average 30 particles, weighing 0.33 gram).*
6. Litter levels in the North Sea show considerable regional variation with highest pollution in the Channel (*86% of Fulmars exceed 0.1g EcoQO limit*) and less pollution further north (*to 53%*).
7. Most North Sea regions suggest small increases in litter ingested by Fulmars; the Southeast North Sea may do slightly better, a pattern driven by results from Belgium and the Netherlands, but none of the trends is significant
8. Shipping, including fisheries, is a major source for marine litter in the North Sea.
9. Implementation of the European Directive on Port Reception Facilities (Directive EC 2000/59/EC) may have contributed to a status quo in marine litter levels, but if reduction is the goal, additional action will be required.

Photo: Dissection of beached Fulmar in the IMARES laboratory

ii. Samenvattend Rapport

Stormvogel Zwerfvuil EcoQO monitoring langs Nederlandse en Noordzeekusten in relatie tot Richtlijn 2000/59/EG betreffende havenontvangstvoorzieningen: resultaten tot 2009.

Operationeel en aan lading gerelateerd scheepsafval vormt een belangrijke bron van zwerfvuil in de zuidelijke Noordzee en veroorzaakt ernstige economische en ecologische schade. Tekortkomingen in afgifteprocedures in havens zijn een belangrijke oorzaak bij het illegaal overboord zetten van afval. De EU heeft dit probleem daarom aangepakt met de 'Richtlijn betreffende HavenOntvangstVoorzieningen' (Richtlijn 2000/59/EC; de zogenaamde 'HOV-Richtlijn'). Verplichte afgifte van afval en indirecte financiering van de kosten vormen de kern van de maatregelen waarmee de Richtlijn correcte afvalafgifte wil stimuleren en afdwingen. Het monitoren van de effecten van de HOV-Richtlijn is noodzakelijk.

In Nederland bestaat al lange tijd een monitoring programma voor zwerfafval op zee dat gebaseerd is op de hoeveelheid plastic in magen van dood aangespoelde zeevogels: de Noordse Stormvogel. Deze vogelsoort foerageert uitsluitend op zee, eet geregeld afval, en braakt onverteerbare resten niet uit, maar moet deze door slijtage in de spiermaag verwerken. Daardoor geeft de maaginhoud een geïntegreerd beeld van de hoeveelheden afval die de vogels in voorgaande weken op zee zijn tegengekomen. Dit Nederlandse graadmeter systeem is internationaal overgenomen door OSPAR als een 'Ecological Quality Objective (EcoQO)' voor de Noordzee (OSPAR 2008; 2010b) en is inmiddels ook kandidaat als indicator voor de 'Goede Milieu Toestand' onder de Kaderrichtlijn Marien (EC 2008, 2010).

Het Ministerie van Infrastructuur en Milieu is voor IMARES de opdrachtgever voor de Nederlandse stormvogel graadmeter. Vergelijkbare internationale monitoring van stormvogels in de hele Noordzee startte in 2002 als onderdeel van het 'Save the North Sea' project uit het EU Interreg IIIB programma, en werd tot en met 2007 voortgezet dankzij steun van de NYK Group Europe Ltd. Na 2007 was de internationale financiering voor de OSPAR EcoQO problematisch. Het Ministerie van Infrastructuur en Milieu had in 2010 behoefte aan monitoringsgegevens over een breder geografisch gebied. Daarom werd in 2010 de onderzoeksopdracht incidenteel verbreed t.o.v. de jaren daarvoor waarin alleen de Nederlandse situatie in kaart werd gebracht. Hierdoor kon, naast de resultaten van de Nederlandse monitoring, ook een update van de Noordzee brede EcoQO tot en met 2009 worden gerealiseerd. In appendices zijn details uitgewerkt voor landen die in deelcontracten uitwerking van hun nationale stormvogelgegevens hebben vastgelegd.

NEDERLANDS GRAADMETER ONDERZOEK

Het jaar 2009

Na een ' schaarste' aan stormvogels in héél 2008, registreerden waarnemers langs de Nederlandse kust in de eerste week van januari 2009 een plotselinge instroom van Noordse Stormvogels. Dit werd vrijwel onmiddellijk gevolgd door een flink aantal dode vogels op onze kust. Bijna de helft van de vogels in deze massasterfte ("wreck") had het donkere veerkleed dat alleen voorkomt in noordelijke arctische gebieden. Op de Nederlandse kust werden in 2009 in totaal 78 stormvogels verzameld, waarvan er 68 een intacte maag hadden. De meerderheid van deze collectie, 55 vogels (46 magen) maakte onderdeel uit van de wreck in januari. De overige 24 vogels (22 magen) waren van later in het jaar. In 66 van de 68 magen (97%) was plastic aanwezig met een gemiddeld aantal van 19.3 stukjes en gewicht van 0.22 gram per maag. Industrieel plastic was met minder dan 2 pellets en 0.04 gram per vogel minder aanwezig dan gebruiksplastics (17 stukjes, 0.18 gram; Tabellen 1a en 2a). Deze getallen suggereren een aanzienlijke afname in plastic t.o.v. vorige jaren, maar dat is een vertekening van de werkelijkheid door de plotselinge instroom van noordelijke vogels in januari die dermate snel dood gingen dat hun maaginhoud geen representatief beeld kon vormen van de situatie in de zuidelijke Noordzee. Inderdaad blijkt dat de januari vogels slechts 0.15 gram plastic per maag hadden, terwijl de vogels uit de rest van 2009 op een meer gebruikelijk niveau van 0.36 gram uitkwamen (Tabel 2b). Gezien het grote aandeel onvolwassen vogels (77%) in dit latere sample, kan het gemiddelde plastic gewicht toch als relatief schoon worden gezien (Fig.3) omdat jonge vogels normaal hoge gehaltes aan plastic bevatten.

Huidige situatie Nederland 2005-2009

Vanwege jaren met kleine samples (zoals in 2008) of incidentele variaties (zoals in januari 2009), wordt in dit graadmetersysteem aanbevolen om het " huidige vervuilings niveau" te beschrijven op basis van het gemiddelde van alle maaginhouden over de voorafgaande 5 jaar, de tijdspanne die ook in de beschrijving van de OSPAR Ecologische Kwaliteitsdoelstelling (EcoQO; zie onder) wordt gehanteerd. Gemiddeld over de jaren 2005-2009, had 95% van de stormvogels plastic in de maag, met gemiddeld ± standaardafwijking 27.3±2.5 stukjes en 0.29±0.03 gram plastic per vogel (Tabel 1b). Dit is een kleine verbetering t.o.v. de eerdere 2004-2008 periode (Tabel 3).

Trends in Nederland

Analyses van trends richten zich op het gewicht aan plastic, en niet zozeer op frequentie van voorkomen of op aantal stukjes. Daarbij wordt onderscheid gemaakt tussen de

- Lange termijn trend over de volledige tijdspanne van de dataset (nu voor Nederland 1979-2009)
- Recente trend, gedefinieerd als de trend over de afgelopen 10 jaar (2000-2009)

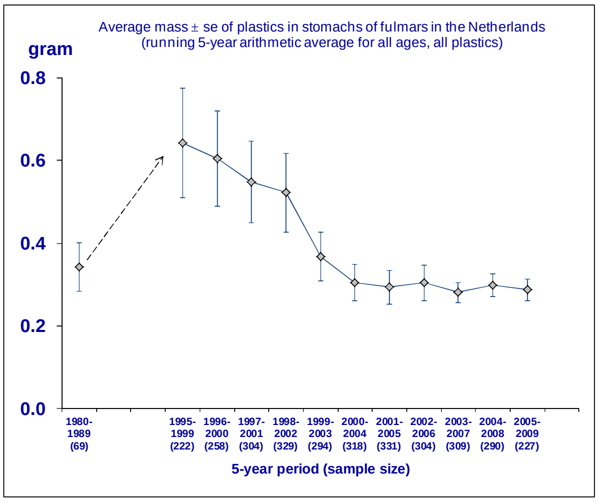
Trends zijn zichtbaar in Fig. i. dat een totaal gemiddelde voor de jaren 1980 vergelijkt met de ' lopende' 5-jaars gemiddeldes vanaf 1995. Significantie van trends (Tabel 4) wordt getest door lineaire regressies van ln-getransformeerde waardes voor plastic gewicht in individuele magen tegen het jaar van verzamelen.

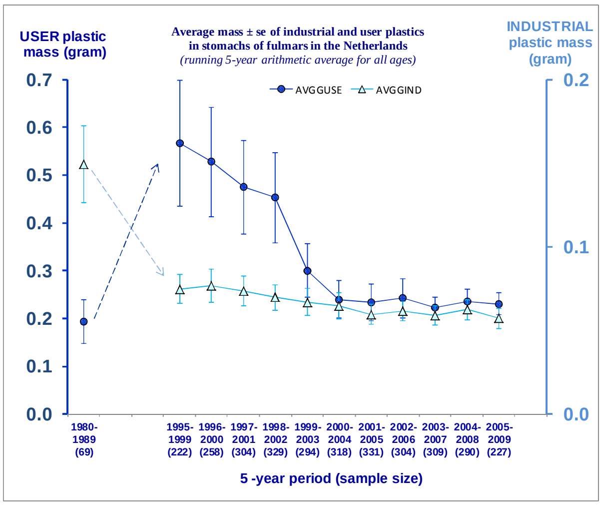
Lange termijn trend 1979-2009

Ondanks de duidelijke veranderingen in Fig.i., bestaat er voor alle plastics tezamen geen significante lineaire trend (Tabel 4a) omdat een toename werd gevolgd door een afname. Dat beeld is vooral bepaald door de gebruiksplastics. Industrieel plastic vertoonde vanaf begin jaren '80 een sterk significante afname ($p<0.001$). Door de verschillende trends is de samenstelling van het plastic in de vogelmagen sterk veranderd: industrieel plastic vertegenwoordigde in de jaren 1980 ca. 50% van het plasticgewicht, nu nog maar rond de 20%. Het aandeel gebruiksplastics nam dus sterk toe (Tabellen 1 en 2). Afnames in industrieel plastics zijn ook in andere delen van de wereld waargenomen.

Recente 10 jaar trend 2000-2009

Tot en met het jaar 2006 lieten de statistische analyses voor 10-jarige trends een significante afname zien in vooral de hoeveelheid gebruiksplastic t.o.v. de piek in de jaren '90. Maar latere analyses, en ook de huidige, zijn niet meer significant (Tabel 4B) omdat veranderingen in zowel industrieel als gebruiksplastics te gering zijn. De tests over de 2000-2009 periode suggereren weliswaar een afname (negatieve t-waardes in tabel 4B) maar in een uiterst traag en statistisch betekenisloos tempo.





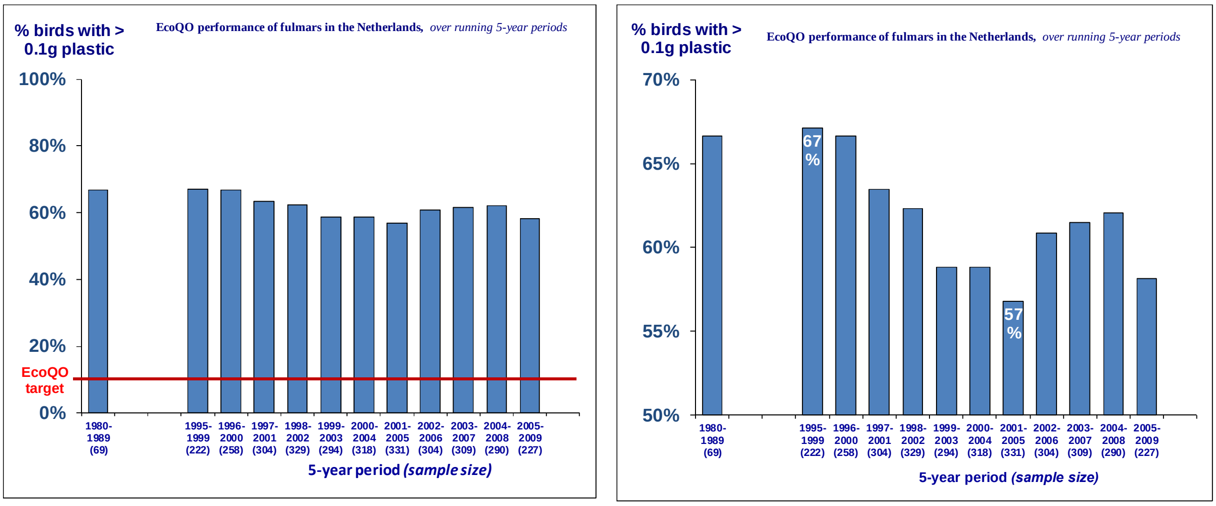
Figuur i ***Trends in plastic gewicht in magen van stormvogels uit Nederland 1980s-2009.*** *De linker grafiek toont de gegevens voor alle plastics tezamen; de rechter grafiek splitst deze op in gebruiksplastics (cirkels, schaal op linker y-as) en industrieel plastic (driehoeken, rechter y-as). Voor een groter formaat afbeelding zie de figuren 1 and 2 in het hoofdrapport. Gegevens zijn weergegeven als gemiddeldes ± standaardafwijking voor plastic gewicht met een enkel gemiddelde voor de jaren 1980 en lopende 5-jaars gemiddeldes vanaf 1995 (dit houdt in dat de 5-jaar datapunten iedere keer één jaar opschuiven).*

Nederlandse ontwikkelingen in termen van de OSPAR EcoQO

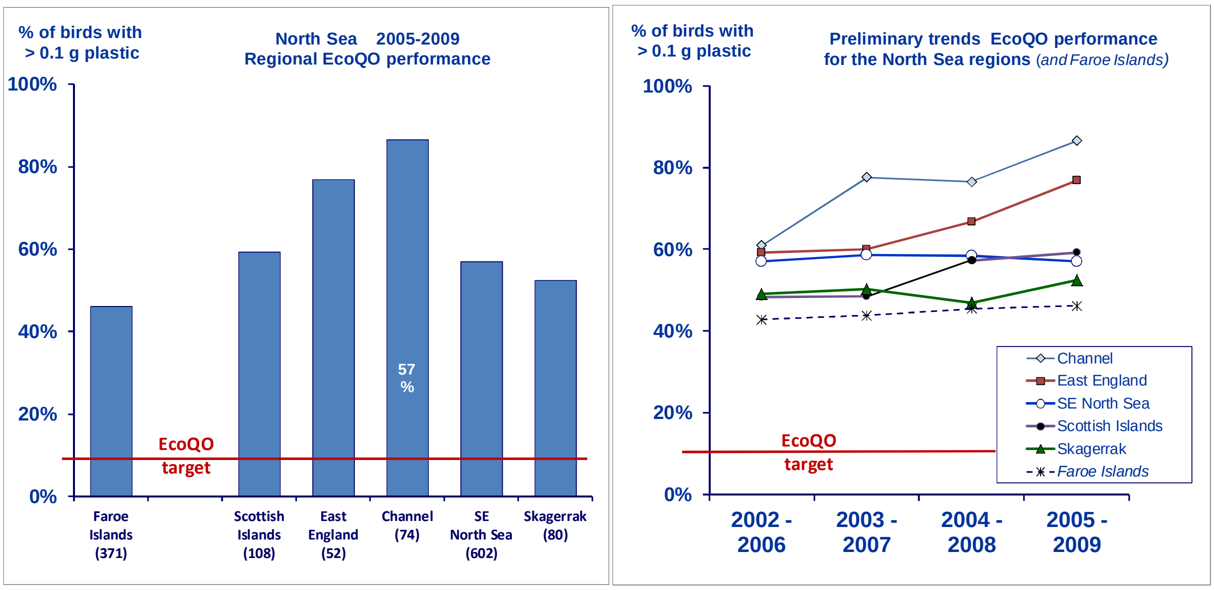
Het Nederlands onderzoek heeft geleid tot de ontwikkeling van de OSPAR Ecologische kwaliteitsdoelstelling (EcoQO) voor zwerfvuil op basis van de hoeveelheid plastics in magen van Noordse Stormvogels (OSPAR 2008, 2010b). Deze benadering wordt inmiddels ook gebruikt voor het opstellen van indicatoren voor een ' Goede Milieu Toestand' in de Europese KaderRichtlijn Marien (EC 2008, 2010). In de EcoQO benadering worden de hierboven beschreven stormvogelgegevens op een iets andere manier bekeken, namelijk als een percentage van de vogels waarbij de hoeveelheid plastic in een maaginhoud een gekozen grensgewicht overschrijdt. OSPAR definieert de 'doelwaarde voor aanvaardbare ecologische kwaliteit' in de Noordzee als de situatie waarin:

> *"minder dan 10% van de Noordse Stormvogels 0.1 gram of meer plastic in de maag heeft, in monsternames van 50 tot 100 aangespoelde vogels uit ieder van 5 verschillende Noordzee regio's gedurende een periode van tenminste 5 jaar"*

Deze doelstelling betekent dat in Fig.ii, de staven in het diagram zouden moeten worden teruggebracht tot onder de rode lijn. Berekend over de 2005-2009 periode, overschreed 58% van de Nederlandse stormvogels het grensniveau van 0.1 g plastic (Tabel 2a; Fig. ii). De betere waarde van 45% voor alleen 2009 (Tabel 2a) is, zoals boven beschreven, vertekend door de wreck van noordelijke vogels in januari. Het is overduidelijk dat alle getallen ver boven de doelwaarde van maximaal 10% liggen, ook al is er sprake van een lichte verbetering t.o.v. de voorgaande periode.



Figuur ii ***EcoQO resultaten in Nederland 1980s-2009*** *– Trend in het percentage van magen dat meer dan 0.1 gram plastic bevatte voor alle in Nederland aangespoelde stormvogels. Voor de jaren 1980 is een enkele waarde berekend, de diagramstaven vanaf 1995 zijn telkens berekend over een 5-jaars periode, die steeds één jaar opschuift. Het linker staafdiagram gebruikt een 100% y-as waarop met een rode lijn de OSPAR EcoQO doelstelling van maximaal 10% vogels met meer dan 0.1g plastic is aangegeven; het rechter staafdiagram toont dezelfde gegevens op een meer gedetailleerde y-as om veranderingen duidelijker te tonen.*



Figuur iii ***EcoQO resultaten en verkenning van trends in de verschillende Noordzee regio's en de Faroe Eilanden 2005-2009.*** *Het linker staafdiagram geeft de EcoQO percentages voor de afzonderlijke regio's en de Faroe Eilanden in verhouding tot de EcoQO doelstelling. In de rechter grafiek worden mogelijke trends bekeken aan de hand van lijnen tussen opeenvolgende 5-jaarsgemiddeldes.*

MONITORING GEGEVENS VOOR DE NOORDZEE

Locaties uit het stormvogelonderzoek zijn gegroepeerd in vijf Noordzee regio's: de Schotse Eilanden (Shetland en Orkney), Oost Engeland (Noord- en Zuidoost), het Kanaal (Normandië en Pas de Calais), de Zuidoostelijke Noordzee (België, Nederland, Duitsland) en het Skagerrak (Skagen Denemarken; Lista Noorwegen; en Zweedse westkust).

In 2005-2009 had, berekend over de hele Noordzee, 95% van de Noordse Stormvogels plastic in de maag, waarbij 60% de 0.1g EcoQO grenswaarde oversteeg. De gemiddelde maaginhoud bevatte 30 stukjes plastic, met een gewicht van 0.33g (details in Tabel 5).

Binnen de Noordzee bestaan duidelijke regionale verschillen, waarbij het meeste plastic wordt gezien in magen van stormvogels uit het Kanaal en de gehaltes zowel langs de west- als oostkust naar het noorden toe afnemen. Regionale EcoQO percentages in 2005-2009 verlopen op die manier van 80% tot 53%. Géén van de vijf regio's voldoet dus aan de OSPAR doelstelling van maximaal 10% vogels met meer dan 0.1g plastic (Fig. iii; Tabel 5). Ook in het minder vervuilde referentie gebied, de Faroe Eilanden, komt in 2005-2009 46% van de vogels boven het 0.1g EcoQO niveau uit. De OSPAR doelstelling voor acceptabele ecologische kwaliteit wordt in het noord Atlantisch gebied op dit moment alleen benaderd in arctisch Canada.

Buiten Nederland zijn de tijdseries eigenlijk nog te kort om goed te kunnen analyseren. Een voorlopige verkenning van de gegevens (Fig. iii, rechter grafiek) suggereert echter dat waar de situatie in de Zuidoostelijke Noordzee vrijwel onveranderd is, er in de andere regio's lichte toenames in plastic vervuiling lijken op te treden. De iets gunstiger lijkende ontwikkeling in de zuidoostelijke Noordzee is voornamelijk te danken aan ontwikkelingen in de Belgische en Nederlandse vogels. Geen van de trends is op dit moment significant en voortzetting van monitoring is nodig om de voorlopige indrukken te bevestigen.

Monitoring gegevens in relatie tot scheepvaartbeleid

Atlantisch zeewater stroomt langs west Europa naar het noorden door het Kanaal en boven langs de Britse Eilanden. De veel hogere vervuiling in het Kanaal wijst erop dat afval ter plekke wordt toegevoegd. De zwaarste vervuiling wordt gezien in Normandië, d.w.z. voordat de grote rivieren in zee uitmonden en scheepvaart gerelateerde vormen van afval zijn hier ook het talrijkst. Dit wijst op de hoge scheepvaart intensiteit als bron. Dit wordt bevestigd door een groot strandonderzoek op Texel (Van Franeker 2005) waarbij scheepsafval van handelsvaart en visserij de hoofdbron van afval waren. Eerdere vermoedens dat industrieel plastic sterker aan instroom van rivieren was gekoppeld kunnen met de huidige gegevens niet worden bevestigd.

Hoewel scheepvaart dus een belangrijke rol heeft in zwerfvuil op zee, heeft de invoering van de EU Richtlijn 2000/59/EC voor HavenOntvangstVoorzieningen niet geresulteerd in significante verbetering in EcoQO percentages in de Nederlandse tijdserie (Fig. ii) of in de trendverkenningen voor de Noordzee regio's (Fig. iii). Verbeteringen in EcoQO percentages werden eind jaren 1990 gezien, dus voorafgaand, niet volgend op de invoering van de Richtlijn. In recente jaren vormen de verhoudingswijs gunstige ontwikkeling in EcoQO percentage in België en Nederland, plus een aanhoudende afname in schuimplastics zwakke signalen dat in dit gebied de opzettelijke lozingen van scheepsafval aan het afnemen zijn.

Ondanks de toegenomen scheepvaartintensiteit en de groei van de plastics in afvalstromen wordt er geen groei in de hoeveelheid afval in zee geconstateerd.

De Richtlijn HavenOntvangstVoorzieningen draagt hieraan vermoedelijk bij, omdat verhoogde scheepvaartintensiteit bij gelijkblijvende hoeveelheden afval in zee wijst op een per schip afgenomen lozing van afval. Dit heeft echter niet kunnen zorgen voor de beoogde verbetering van milieukwaliteit. Daadwerkelijke verbetering van milieukwaliteit zal aanvullende acties vereisen.

CONCLUSIES

1. Noordzee landen streven naar een Ecologische Kwaliteitsdoelstelling (ECOQ) waarbij minder dan 10% van de Noordse Stormvogels een grenswaarde van 0.1 gram plastic in de maag overschrijdt.
2. In Nederland heeft momenteel 58% van de stormvogels meer dan 0.1 gram plastic in de maag *(227 stormvogels 2005-2009: 95% heeft plastic, gemiddeld 27 stukjes en 0.29g).*
3. Lange termijn gegevens voor Nederland tonen een sterke toename van zwerfvuil vanaf begin jaren 1980 tot midden jaren '90, gevolgd door een snelle afname tot kort na de eeuwwisseling maar daarna stabilisatie en geen significante verbeteringen.
4. De samenstelling van door stormvogels ingeslikt plastic is sinds de jaren 1980 sterk veranderd met een significant afgenomen deel industrieel plastic en een toegenomen deel gebruiksplastics.
5. Gemeten over de hele Noordzee overschrijdt 60% van de stormvogels het 0.1g EcoQO niveau *(916 stormvogels 2005-2009: 95% heeft plastic in de maag, gemiddeld 30 stukjes en 0.33 g).*
6. Regionale variatie in de Noordzee is aanzienlijk, met de hoogste vervuiling in het Kanaal (*86% van stormvogels boven de 0.1g EcoQO waarde*) en naar het noorden toe afnemende vervuiling (*tot 53%)*
7. De meeste Noordzee regio's lijken een lichte toename in hoeveelheid plastic te ondergaan: de zuidoostelijke Noordzee doet het de laatste jaren beter dankzij resultaten voor België en Nederland. Geen van dit soort trends is echter significant.
8. Scheepvaart, inclusief visserij, vormt een belangrijke bron van zwerfvuil in de Noordzee.
9. Invoering van de Europese Richtlijn voor HavenOntvangstVoorzieningen (Directive EC 2000/59/EC) heeft mogelijk bijgedragen aan stabilisering van het vervuilingsniveau in de zuidelijke Noordzee, maar voor een afname van zwerfvuil zal aanvullende actie noodzakelijk zijn.

Foto: Dissectie van een gestrande Noordse Stormvogel in het IMARES laboratorium

1. Introduction

Marine litter, in particular plastic waste, represents an environmental problem in the North Sea and elsewhere, with considerable economic and ecological consequences. In 2005, a study on the island of Texel revealed that each day, on each km of beach, 7 to 8 kg of debris washed ashore (Van Franeker 2005): roughly half of the debris was wood, the other half synthetic materials, with relatively minor contributions from other materials such as glass and metals. On Texel, the main source of the debris, estimated up to 90% of mass, was related to activities at sea, i.e. shipping, fisheries, aquaculture and offshore industries.

The **economic consequences** of marine litter affect many stakeholders. Coastal municipalities are confronted with excessive costs for beach clean-ups. Tourism suffers damage because visitors avoid polluted beaches, especially when health-risks are involved. Fisheries are confronted with a substantial by-catch of marine litter which causes loss of time, damage to gear and tainted catch. Shipping suffers financial damage and -more importantly- safety-risks from fouled propellers or blocked water-intakes. Coastal litter blowing inland can even seriously affect farming practices. The overall economic damage from marine litter is difficult to estimate, but detailed study in the Shetlands with additional surveys elsewhere indicate that even local costs may run into millions of Euros. (Hall 2000; Lozano and Mouat, 2009; Mouat et al., 2010).

The **ecological consequences** of marine litter are most obvious in the suffering and death of marine birds or mammals entangled in debris. Entangled whales are front page news and attract a lot of public attention. However, only a small proportion of entanglement mortality becomes visible among beached 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 sea-turtles. It does cause direct mortality but the major impact may well occur through reduced fitness of many individuals. Sub-lethal effects on animal populations remain largely invisible. In spite of spectacular examples of mortality from marine litter, the real impact on marine wildlife therefore remains difficult to estimate (Laist 1987, 1997; Derraik 2002). Plastics gradually break down to microscopically small particles, but these may pose an even more serious problem (Thompson *et al*. 2004). Concern about microplastics attracts more and more attention as evidence is growing that plastics in seawater strongly bind organic pollutants and microplastics may enter the base of the food-web by ingestion by filter-feeding marine organisms (Endo et al 2005; Teuten et al. 2007; Browne et al. 2008; Moore 2008; Arthur et al 2009; Thompson et al. 2009). Thus, in addition to the toxic substances incorporated into plastics in the manufacturing process, plastics may concentrate much more pollutants from the environment and act as a pathway boosting their accumulation in marine organisms. Evidently, this same mechanism operates at all levels of organisms and sizes of ingested plastic material, from small zooplankton filter-feeders to large marine birds and mammals, but it is the microplastic issue and their ingestion by small filter-feeders that has emphasized the potential scale and urgency of the problem of marine plastic litter, as it may ultimately affect human food quality and safety as well. Accumulation of marine plastic litter, including a ‘soup’ of microplastics, in all major gyres of the oceans have emphasized the global scale of the marine litter problem (Moore et al.2008; Law et al 2010; Maximenko et al. 2011)

Recognizing the negative impacts from marine debris, 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 been intensified by for example the EU-Directive 2000/59/EC on Port Reception Facilities (EC 2000), the Declaration from the North Sea Ministerial Conference (2002) in Bergen, and recently in the European Marine Strategy Framework Directive (EC 2008, EC 2010).

Policy initiatives have recognized the need to use quantifiable and measurable aims. Therefore, the North Sea Ministers in the 2002 Bergen Declaration decided to introduce a system of Ecological Quality Objectives for the North Sea (EcoQO's). For example, the oil pollution situation in the North Sea is measured by the rate of oil-fouling among beached Guillemots (*Uria aalge*) with an EcoQO target of less than 10% of beached Guillemots having oil on the plumage (OSPAR 2005). Similarly, OSPAR decided to use the abundance of plastic in stomachs of seabirds, *in casu* the Northern Fulmar (*Fulmarus glacialis*) to measure quality objectives for marine litter. (OSPAR 2008, 2010a, 2010b). The Fulmar EcoQO monitoring has been included as an indicator for marine litter in the approach for Good Environmental Status in the European Marine Strategy Framework Directive (Galgani et al. 2010, EC 2010).

Within the Netherlands, the Ministry of Infrastructure and the Environment (IenM) has a coordinating role in governmental issues related to the North Sea environment. As such, IenM is involved in the development of environmental monitoring systems ("graadmeters") for the Dutch continental shelf area. As a part of this activity, IenM has commissioned several earlier projects by IMARES working towards a Fulmar-Litter-EcoQO. The first pilot project for the North Sea Directorate considered stomach contents data of Dutch Fulmars up to the year 2000 and made a detailed evaluation of their suitability for monitoring purposes (Van Franeker & Meijboom 2002). A series of later reports commissioned by the Directorate-General for Civil Aviation and Maritime Affairs (DGLM) (see 'References') have provided annual updates on the Dutch time-series up to the year 2008 (van Franeker 2010), paying special attention to shipping issues and EU Directive 2000/59/EC.

Internationally, as of 2002, the Dutch Fulmar research was expanded to all countries around the North Sea as a project under the ***Save the North Sea (SNS)*** program. SNS was co-funded by EU Interreg IIIB over period 2002-2004 and aimed to reduce littering in the North Sea area by increasing stakeholder awareness. The Fulmar acted as the symbol of the SNS campaign. The SNS Fulmar study was published as Van Franeker *et al*. 2005. Findings strongly supported the important role of shipping (incl. fisheries) in the marine litter issue. For further publications of the SNS Fulmar study see e.g. Save the North Sea 2004, Van Franeker 2004b and 2004c, Edwards 2005, Guse *et al* 2005, Olsen 2005. After completion of the European SNS project, the international work was continued through CSR awards from the NYK Group Europe Ltd. These funds contributed to North Sea EcoQO updates for 2006 (Van Franeker & the SNS Fulmar Study Group 2008) and a peer reviewed scientific publication on the EcoQO methods with data up to 2007 (Van Franeker *et al. in press 2011*). These awards were used also to promote Fulmar work in other areas of the world (e.g. Canadian Arctic and Pacific) and to explore the use of other bird species in areas where Fulmars do not occur.

The current assignment from the Dutch Ministry of IenM, through its Directorate-General for Civil Aviation and Maritime Affairs (DGLM) included the following tasks:

- To update the Dutch time series on litter in stomach contents of Fulmars with the data from year 2009 and to continue co-ordination of the beached bird sampling in the Netherlands
- To fill gaps in stomach analyses of fulmars from other North Sea countries[1] for years 2008 and 2009 and integrate all data into a full North Sea EcoQO update up to 2009, giving special attention to details that could relate to the role of shipping

[1] *Norway paid a 2008 analysis of its material in relation to OSPAR agreements; the UK currently finances analyses of North Sea material for years 2008 to 2010 in relation to the Marine Strategy Framework Directive*

2. The Fulmar as an ecological monitor of marine litter

The interpretation of monitoring information presented in this report requires a summary of earlier findings.

In their pilot study, Van Franeker & Meijboom (2002) discussed the feasibility of using stomach contents of beached Northern Fulmars to measure changes in the litter situation off the Dutch coast in an ecological context. Samples of Fulmars available for the feasibility study mainly originated from the periods 1982 to 1987 and 1996 to 2000, with smaller number of birds from the years in between.

Reasons for selection of the Fulmar out of a list of potential seabird monitoring species are of a practical nature:

- Fulmars are abundant in the North Sea area (and elsewhere) and are regularly found in beached bird surveys, which guarantees supply of an adequate number of bird corpses for research.
- Fulmars are known to consume a wide variety of marine litter items.
- Fulmars avoid inshore areas and forage exclusively at sea (never on land).
- Fulmars do not normally regurgitate indigestible items, but 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, averaging pollution levels over a foraging space and time span that avoids bias from local pollution incidents.
- Historical data are available in the form of a Dutch data series since 1982 (one earlier 1979 specimen); 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 (they regurgitate indigestible remains); are coastal only and/or find part of their food on land (e.g. *Larus* gulls); ingest litter only incidentally (e.g. North Sea alcids) or are too infrequent in beached bird surveys for the required sample size or spatial coverage (e.g. other tubenoses or Kittiwake *Rissa tridactyla*).

Beached birds may have died for a variety of reasons. For some birds, plastic accumulation in the stomach is the direct cause of death, but more often the effects of litter ingestion act at sub-lethal 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 a range of other potentially relevant parameters are determined. Standardized dissection procedures for EcoQO monitoring have been described in detail in a manual (Van Franeker 2004b). Stomach contents are 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 are recorded on presence or absence ("incidence"), the number of items, and the mass of subcategory (see methods). For efficiency/economy reasons, some of the details in manual and earlier reports have been reduced.

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, cause of death, 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.

A very 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). This means that our results, which are largely based on beached starved birds, are representative for the 'average' healthy Fulmar living in the southern North Sea.

Only age was found to have an effect on average quantities of ingested litter, adults having less plastic 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 defence of nest-sites. Another factor could be that foraging experience may increase with age. Understanding of the observed age difference in plastic accumulation is poor. In search of better understanding of such issues, Chevron Upstream Europe has funded a cooperative project with the Faroese Fisheries Laboratory. Using Fulmars from the Faroe Islands, we investigate seasonal and age related variations in stomach contents. On the Faroe Islands, Fulmars are hunted for consumption and large numbers of samples are easily obtained. Additional samples have been obtained from fisheries by-catch in the area. Stomach contents are analysed for both normal diet (Faroese component in the study) and for accumulated litter (Dutch contribution to the study). Samples have been obtained from all months of the year during several years and these are currently analysed.

Although age has been shown to affect absolute quantities of litter in stomach contents, changes over time follow the same pattern in adults or non-adults. As long as no directional change in age composition of samples is observed, trends may be analysed for the combined age groups. However, background information for the presentation of results and their interpretations always requires insight in age composition of samples.

Significant long term trends from 1982 to 2000 were detected in incidence, number of items and mass of industrial plastics, user plastics and suspected chemical pollutants (often paraffin-like substances). Over the 1982-2000 period, only industrial plastics decreased while user plastics significantly increased. When comparing averages in the 1980s to those in the 1990s, industrial plastics approximately halved from 6.8 granules per bird (77% incidence; 0.15g per bird) to 3.6 granules (64%; 0.08g). User-plastics almost tripled from 7.8 items per bird (84%; 0.19g) to 27.6 items (97%; 0.52g).

Analysis of variability in data and Power Analysis revealed that reliable figures for litter in stomachs in a particular region are obtained at a sample size of about 40 birds per year and that reliable conclusions on change or stability in ingested litter quantities can be made after periods of 4 to 8 years, depending on the category of litter. Lower annual sample sizes are no problem, but will lengthen the periods needed to draw conclusions on regional levels and trends.

Mass of litter, rather than incidence or number of items, should be considered the most useful unit of measurement in the long term. Mass is also the most representative unit in terms of ecological impact on organisms. Incidence loses its sensitivity 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 appears to vary with changes in plastic characteristics.

The pilot study concluded that stomach content analysis of beached Fulmars offers 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. As indicated there is an increasing awareness of the dangers from microplastics, but monitoring quantities and effects in these species is more difficult than that of intermediate sized plastics in seabirds.

The pilot study recommended that Dutch Fulmar-Litter monitoring should focus on mass of plastics (industrial plastic and user) and suspected chemicals. Each of these represents different sources of pollution, and thus specific policy measures aimed at reduced inputs. Because no funding was obtained to work on suspected chemicals, this element has been dropped and plastics have become the main focus. However, data-recording procedures are such that at the raw data-level, various sub-categories of plastics, other rubbish and suspected chemicals continue to be recorded by number and mass, and can be extracted from databases, should the need arrive.

After publication of the pilot study, the Dutch monitoring has continued annually and has resulted in a series of reports (Van Franeker et al 2003 to 2010) that initially confirmed further decrease of industrial and especially user plastics but that later noted a halt to such trends and a lack of further change.

Internationally, the Fulmar Litter monitoring was boosted by the 'Save the North Sea (SNS)' campaign 2002-2004, which was co-funded by EU Interreg IIIB and aimed at increasing awareness among stakeholders so as to reduce littering behaviour. Expanding the Dutch Fulmar study to locations all around the North Sea was one of the project components. Co-operation was established with interested groups in all countries around the North Sea. The final project report (Van Franeker et al. 2005) showed that Fulmars from the southern North Sea had almost two times more plastic in the stomach than Fulmars from the Scottish Islands, and almost four times as much as that in a small sample from the Faroe Islands. Location differences and relative abundances of different types of litter suggested a major role of shipping, and showed that the bulk of the litter problem in the North Sea region is of local origin.

Also in 2002, North Sea Ministers in the Bergen Declaration, decided to start a system of '*Ecological Quality Objectives (EcoQO's) for the North Sea*'. One of the EcoQO's to be developed was for the issue of marine litter pollution, using stomach contents of a seabird, the Fulmar, to monitor developments, and to set a target for 'acceptable ecological quality'. OSPAR was requested to look after implementation of the ecological quality objectives. Since then, a number of steps have been taken, based on reports from the Dutch studies and the Save the North Sea project. The current wording of the EcoQO target level (OSPAR 2010b) is:

> *"There should be less than 10% of northern fulmars (Fulmarus glacialis) having more than 0.1 gram plastic particles in the stomach in samples of 50 to 100 beach-washed fulmars from each of 4 to 5 different areas of the North Sea over a period of at least 5 years".*

As recommended from the Dutch studies, the **mass** of plastics forms the basis of the EcoQO monitoring system. But rather than using average plastic mass for the target definition, a combination is used of frequency of occurrence of plastic masses above a certain critical mass level (10%; 0.1g). The background of such approach is that a few exceptional outliers can have a strong influence on the calculated average. The wording of the target level basically excludes influence of exceptional outlying values. A similar effect can be obtained by calculating mean values from logarithmically transformed data. The OSPAR Fulmar EcoQO has been published in a background document (OSPAR 2008) and its implementation was included in the OSPAR Quality Status Report (OSPAR 2010a and b).

As indicated in the introduction, the international work was continued and expanded after the SNS project. The EcoQO approach to marine litter is now an element for assessment of 'Good Environmental Status' in the European Marine Strategy Framework Directive (Galgani et al. 2010; EC 2010). Quality of the methodology has been established by publications in peer reviewed scientific articles (Ryan et al. 2009; Van Franeker et al. *in press 2011*) and is used by researchers in the Canadian arctic and in the Pacific. The results of Fulmar studies were also used in the UNEP yearbook 2011, which devoted a chapter to the global problem of marine litter (Kershaw et al. 2011).

Photo:

Demonstration of Fulmar dissection at the OSPAR Ministerial Conference in Bergen, September 2010.

3. Shipping, marine litter and policy measures

In historic times, waste products from ships were discarded almost anywhere and at any time. The relatively low intensity of shipping and generally degradable nature of wastes allowed such practice to continue for centuries without significant problems except inside harbour areas. However, exponential population growth and global industrialization has boosted marine transports by fast mechanically-powered ships with ever increasing quantities of poorly degradable and toxic wastes from fuel, cargo and household practises. Old habits are hard to change, particularly if such change involves costs in an extremely competitive international industry such as shipping. For example, the dramatic environmental consequences of oil discharges from ships were already known in the early 1900s. More than a century later, under continuous public pressure and a continuous sequence of policy measures, the oil pollution problem is to some extent under control, but definitely not solved.

Compared to the problems from dumping of oil or toxic wastes, the issue of disposal of 'garbage' into the marine environment has long been considered of minor importance. It might still be considered that way if not for plastics. Plastics, although known since the early 1900s, started their real development only after 1960. Since then, they have found their way into almost every application, replacing old materials in existing products, and creating new use in for example an endless array of 'disposable' packaging products.
Unfortunately, the same factors that made plastics such a popular product have resulted in them becoming an environmental problem. Low production costs have promoted careless use and low degradability leads to accumulation in the environment. In 2007, the world production of plastics reached 245 million tons, over 40% of which is used for packaging; annual growth rates of between 5 to 10% were interrupted by the economic crisis in 2008, but this is probably no more than a temporary interruption (PlasticsEurope 2010).

At the same time, intensity of shipping has increased. Between 1994 and 2008, the world's active merchant fleet grew from 437 to 742 million gross tons. Fleets grow faster and faster. Over the 1994-2003 decade, tonnage showed 30% growth, matched by a similar growth over the 5 year period 2003-2008. The tonnage of new merchant ships (>100 gtons) leaving shipyards was 18 million gross tons in 1994 and reached an all-time peak of 57 million gross tons over 2007. (Department for Transport 2008).

Marine litter originates from a variety of sources, including merchant shipping, fisheries, offshore industry, recreational boating, coastal tourism, influx from rivers or direct dumping of wastes along seashores. The relative importance of various sources differs strongly in different parts of the world, and is almost impossible to quantify. Dutch Coastwatch studies (e.g. Stichting de Noordzee 2003) score litter into categories 'from sea' (shipping, fisheries, offshore); 'beach-tourism'; 'dumped from land'; and 'unknown'. In the Netherlands, the 'from sea' category consistently represents in the order of 40% of litter items recorded. The 'unknown' category scores a similar percentage. Considerable uncertainties are linked to this categorization. More specific information may come from the OSPAR initiative for monitoring litter on beaches in a somewhat more systematic approach. In a first German report (Fleet 2003), ten years of Coastwatch-like surveys, plus two years of the more detailed OSPAR pilot project, were evaluated. From both studies it is concluded that shipping, fisheries and offshore installations are the main sources of litter found on German North Sea beaches. The larger proportion of litter certainly originates from shipping, with a considerable proportion of this originating in the fisheries industry. In the Netherlands, data to this effect were collected in a large beach litter study on Texel (van Franeker 2005) suggesting that up to 90% of plastic litter originates from shipping and fisheries in the Dutch area. So, although there may be uncertainties in details, there is little doubt that waste disposal by ships is one of the important sources of marine litter worldwide, a fact also recognized by the International Maritime Organization (IMO) in a specific 'garbage-annex' to the MARPOL Convention.

The International Convention for the Prevention of Marine Pollution from Ships (MARPOL 73/78) entered into force on 2nd October 1983 for Annexes I (oily wastes) and II (bulk liquid chemicals), but its Annex

V, covering garbage, only achieved sufficient ratifications to enter into force on 31st December 1988. MARPOL Annex V contains the following main prohibitions for discharge of solid wastes:

- No discharge of plastics.
- No discharge of buoyant dunning, lining or packaging material within 25 nautical miles (nm).
- No discharge of garbage within 12 nm. Food waste may be discharged if ground to pieces smaller than one inch.
- No discharge of any solid waste, including food waste, within 3 nm.

Unfortunately, control of compliance with Annex V regulations on ships is difficult. During Port State Inspections, garbage-related issues do not receive the strongest attention. Nevertheless, in the year 2002, 13% of observed deficiencies were related to Annex V garbage regulations (OECD-MTC 2003).
Currently, MARPOL Annex V is under revision from the Marine Environment Protection Committee (MEPC).

In the European region, and especially the North Sea area, the sheer intensity of merchant shipping and fisheries makes them an undisputed source of marine litter. From that background, North Sea states promoted that the North Sea received the status of MARPOL Special Area for its annexes I (oil) and V (garbage). Amendments to that effect were made in 1989, and the Special Area status for the North Sea entered into force in February 1991. "Special Areas" under MARPOL Annex V have a more restrictive set of regulations for the discharge of garbage, with the main additions being:

- No discharge, not only of plastics, but also of any sort of metal, rags, packing material, paper or glass.
- Discharge of food wastes must occur as far as practicable from land, and never closer than 12 nm.

Within the European Union, progress under worldwide MARPOL regulations was considered insufficient. In the port of Rotterdam, approximately 5 to 10% of visiting ships used port reception facilities. Clearly not every ship needs to discharge wastes at every port visit, but the level of waste delivery was clearly too low. High costs of proper disposal in combination with low risk of being fined for violations are a clear cause. Poor functioning of available reception facilities definitely plays a role as well. Compliance with MARPOL regulations is hard to enforce at sea, especially when many ships fall under jurisdiction of cheap flag-states with little concern for environmental issues. Compliance can only be promoted by measures that can be enforced when ships visit the harbour. From this perspective, the European Commission and parliament have installed the EU-Directive on Port Reception Facilities for ship-generated waste and cargo residues (Directive 2000/59/EC). Key elements of the Directive are:

- Obligatory disposal of all ship-generated waste to reception facilities before leaving port. Ship-generated waste includes operational oily residues, sewage, household and cargo-associated waste, but not residues from holds or tanks.
- Indirect financing, to a 'significant' degree, of the delivery of ship-generated waste. Finances for such 'free' waste reception should be derived from a fee system on all ships visiting the port. Delivery of cargo residues remains to be paid fully by the ship
- Ports need to develop and implement a 'harbour waste plan' that guarantees appropriate reception and handling of wastes

The term 'Significant' was later identified as meaning 'in the order of at least 30%'. Implementation date for the Directive was December 2002, but unfortunately suffered some delay in several countries. In the Netherlands, the Directive became implemented in late 2004, operating at or above the minimum level of indirect financing depending on the harbour. On an annual basis, results are evaluated by the Minister of Infrastructure and the Environment (IenM) in which also the results of the Fulmar-Litter-EcoQO monitoring are being used. This tool complements surveys of quantities of litter delivered in ports, or beach surveys for quantities of waste washing onto beaches. These approaches have their specific merits but do not measure residual levels of litter in the marine environment itself. The Fulmar-Litter-EcoQO does look at this marine environment and at the same time places such information in the context of ecological effects.

4. Materials and Methods

In 2009 IMARES has continued the collection of beached Fulmars from Dutch beaches with the assistance of the Dutch Seabird Group (Nederlandse Zeevogelgroep NZG) through its Working Group on Beached Bird Surveys (Nederlands Stookolieslachtofffer Onderzoek - NSO). Also several coastal bird rehabilitation centres support the collection program. Since the start of the ***Save the North Sea*** project in 2002, IMARES co-ordinates similar sampling projects at a range of locations in all countries around the North Sea. Organizations involved differ widely, and range from volunteer bird groups to governmental beach cleaning projects.

Bird corpses are stored frozen until analysis. Standardized dissection methods for Fulmar corpses have been published in a dedicated manual (Van Franeker 2004b) and are internationally calibrated during annual workshops. Stomach content analyses and methods for data processing and presentation of results were described in full detail in Van Franeker & Meijboom (2002) and updated in later reports. Scientific reliability of the methodology was recently established by acceptance of a peer reviewed scientific article, currently in press with the journal Environmental Pollution (van Franeker et al. *in press 2011*)

For convenience, some of the methodological information is repeated here in a condensed form.

At dissections, a full series of data is recorded that is of use to determine sex, age, breeding status, likely cause of death, origin, and other issues. Age, the only variable found to influence litter quantities in stomach contents, is largely determined on the basis of development of sexual organs (size and shape) and presence of *Bursa of 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). Further details are provided in Van Franeker 2004b. In the near future, an updated version of the manual should be published to improve details and maximize efficiency of methods.

After dissection, stomachs of birds are opened for analysis. Stomachs of Fulmars have two 'units': initially food is stored and starts to digest in a large glandular stomach (the *proventriculus*) after which it passes into a small muscular stomach (the *gizzard*) where harder prey remains can be processed through mechanical grinding. In early phases of the project, data for the two individual stomachs were recorded separately, but for the purpose of reduction in monitoring costs, the contents of proventriculus and gizzard are now combined.
Stomach, contents are carefully rinsed in a sieve with a 1mm mesh and then transferred to a petri dish for sorting under a binocular microscope. The 1 mm mesh is used because smaller meshes become clogged with mucus from the stomach wall and with food-remains. Analyses using smaller meshes were found to be extremely time consuming and particles smaller than 1 mm seemed rare in the stomachs, contributing little to plastic mass.

If oil or chemical types of pollutants are present, these may be sub-sampled and weighed before rinsing the remainder of stomach content. Although this was a standard component at the start of our studies, requirements for the Dutch “graadmeter” and international EcoQO have a focus on plastic or at best MARPOL Annex V litter types. Thus, for financial efficiency, potential chemical pollutants in the stomachs are no longer part of the project. If sticky substances hamper further processing of the litter objects, hot water and detergents are used to rinse the material clean as needed for further sorting and counting under a binocular microscope.

The following categorization is used for plastics and other rubbish found in the stomachs:

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, beads or granules. They can be considered as "raw" plastic or a half-product in the form of 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, colorants, anti-oxidants, softeners, biocides, etc.) that depend on the user product to be made. For the time being, included in this category are 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 in 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 or less hard plastic items as used in a huge number of applications (bottles, boxes, toys, tools, equipment housing, toothbrushes, lighters etc.);
      1.2.5. **other (oth)**, for example cigarette filters, rubber, elastics etc., so items that are 'plastic-like' or do not fit into a clear category.

2. **RUBBISH (RUB)** other than plastic:
   2.1. **paper (pap)** which besides normal paper includes silver paper, aluminium foil 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. **fish hook (hoo)** from either sport-fishing or long-lining.

Further optional categories of stomach contents

3. **POLLUTANTS (POL)**
   3.1.1. for items indicating industrial or chemical waste remains such as slags (the remains of burning ovens, e.g. remains of coal or ore after melting out the metals); tar-lumps (remains of mineral oil); chemical (lumps or 'mud' of paraffin-like materials or sticky substances arbitrarily judged to be unnatural and of chemical origin) and feather-lumps (indicating excessive preening by the bird of feathers sticky with oil or chemical pollutants).
4. **NATURAL FOOD REMAINS (FOO)**
   4.1.1. Numbers of specific items may be recorded in separate subcategories (fish otoliths, eye-lenses, squid-jaws, crustacean remains, jelly-type prey remains, scavenged tissues incl. feathers, insects, other).
5. **NATURAL NON-FOOD REMAINS (NFO)**
   5.1.1. Numbers of subcategories e.g. plant-remains, seaweed, pumice, stone and other may be recorded.

For the main categories 1 (plastic) and 2 (rubbish) we record for each bird and each (sub)category:

- incidence (Presence or absence) and
- abundance by number (count of Number of items)
- abundance by mass (Weight in grams) using Sartorius electronic weighing scale after a one to two day period of air drying at laboratory temperatures. For marine litter (categories 1 to 3 above),

this is done separately for all subcategories. In the early Fulmar study we also weighed the natural-food and natural-non-food categories as a whole, but this was discontinued in 2006 to reduce costs. Weights are recorded in grams accurate to the 4th decimal (= tenth of milligram).

To be able to sort out items of categories 1 and 2, all other materials in the stomachs described in categories 3 to 5, have to be cleaned out. However in these latter categories, further identification, categorization, counting, weighing and data-processing is not essential for the EcoQO. Whether details are recorded depends of the interest of the participating research group and their reasons to collect beached Fulmars.

In addition to the acronyms used for (sub)categories as above, further acronyms may be used to describe datasets. Logarithmic transformed data are initiated by 'ln'; mass data are characterized by capital G (gram) and numerical data by N(number). For example lnGIND refers to the dataset that uses ln-transformed data for the mass of industrial plastics in the stomachs; acronym NUSE refers to a dataset based on the number of items of user plastics.

Analysis and presentation of results

Data from dissections and stomach content analysis are recorded in Excel spreadsheets and next stored in Oracle relational database. GENSTAT 8 is used for statistical tests. As concluded in the pilot study (Van Franeker & Meijboom 2002) and later reports, statistical trend analysis is conducted using mass-data. Tests for trends over time are based on linear regressions fitting ln-transformed plastic mass values for individual birds on the year of collection. Logarithmic transformation is needed because the original data are strongly skewed and need to be normalized for the statistical procedures. Tests for 'long term' trends use the full data set; 'recent' trends only use the past ten years of data.

For earlier Dutch reports, the focus was on such trends rather than on a final target. However, OSPAR (2010b) words its Ecological Quality Objective (EcoQO) for levels of litter (plastic) in stomachs of fulmars (the '*Fulmar-Litter-EcoQO*') as:

> *"There should be less than 10% of northern fulmars (Fulmarus glacialis) having more than 0.1 gram plastic particles in the stomach in samples of 50 to 100 beach-washed fulmars from each of 4 to 5 different areas of the North Sea over a period of at least 5 years".*

Thus, the information requested now focuses on the category of 'total plastic' and pooled data for 5-year periods over larger areas. Number and mass data for 5-year periods are ***not*** derived from the annual averages, but are calculated from all individual birds over the full 5 years with data presented as arithmetic averages ± standard errors (se). Averages are calculated over all birds, so including the ones that had no plastic at all in the stomach. Time related changes are illustrated in graphs by running 5-year averages, each time shifting one year and thus overlapping for four years.

Sometimes sample sizes may not be large enough to average out the impact of occasional extreme outliers. Therefore data are often additionally presented as geometric means, calculated from logarithmic data values. Logarithmic transformation reduces the role of the higher values, but as a consequence the geometric mean is usually considerably lower than the arithmetic mean for the same data. In mass data for plastics in the Fulmar stomachs, geometric means are only about one third to half of the arithmetic averages. Geometric means thus do not properly reflect absolute values, but are useful for comparative purposes between smaller sample sizes, for example when looking at annual data rather than at 5-year-periods.

For North Sea EcoQO analyses, results of the separate locations in the Fulmar study are grouped into five areas or regions: the Scottish Islands (Shetland and Orkney), East England (northeast and southeast England), the Channel (Normandy and Pas de Calais), South-Eastern North Sea (Belgium, Netherlands and Germany), and the Skagerrak (Skagen Denmark, Lista Norway and Swedish west coast).

EcoQO compliance or performance is defined as the percentage of birds in a sample that has 0.1 g or more plastic mass in the stomach. The EcoQO format is a highly simplified form of data-presentation. In the background however, details of various subcategories of litter continue to play an important role for correct interpretation of the EcoQO metric.

Photo

Trawl net washing ashore on Texel, the Netherlands

5. Results & Discussion

5.1. Monitoring in the Netherlands 1979-2009 and trends

Monitoring data for the Netherlands 2009

In the preceding report period 2008, substantial search effort of the volunteers of the Dutch Seabird Group (NZG) and other participating organizations resulted in only 22 Fulmar corpses, 20 of which contained usable intact stomachs. Coastal and at sea observations reported very few Fulmar observations in the southern North Sea. Immediately following the difficult sampling year 2008, in the first week of January 2009, an influx of fulmars in poor body condition in the southern North Sea was observed. Within a few days, considerable numbers of birds were found dead on beaches. This wreck in January contributed strongly to the overall sample of 79 Fulmars from Dutch beaches collected in 2009. Of these corpses, 11 had damaged or absent stomachs, leaving 68 intact stomachs for the monitoring program. The majority, 55 birds (46 stomachs) originated from the wreck in January, the remaining 24 corpses (22 stomachs) were found in other months.

Overall, among the 68 stomachs, 66 contained plastic (97% incidence), with an overall average number of 19.3 items per bird and average mass of 0.22 gram plastic per bird. Industrial plastics represented a minority (less than 2 ‘pellets’ per bird, 0.04g) compared to discarded user plastics (over 17 items and 0.18g per bird) (Tables 1a and 2a).

These 2009 figures show substantial lower abundance of plastics than those of previous years (Table 2). For a considerable part, this sudden drop is believed to be an artefact linked to the events in early January 2009 which suggest a sudden influx of birds from arctic regions into the Dutch continental shelf area. A remarkable 46% of the beached Fulmars collected in January had dark plumage colour indicating arctic origin. In usual winter conditions, at most 10-20% of beached Fulmars are of such origin. The sudden influx into the southern North Sea, in combination with the colour-phase proportions suggests that the stomachs of these January birds were not representative for foraging in the Dutch continental shelf area. Indeed, birds collected in January 2009 had unusually low abundance of plastic in the stomach, with plastic mass of 0.15g compared to a more ‘usual’ 0.36g for the birds collected in the remainder of the year (Table 2b). However, considering the large proportion of younger birds (77%) in the latter sample, also the 0.36g average plastic mass may be characterized as relatively clean (Fig. 3) because young birds have normally higher loads of plastic. Incidental events such as in 2009 reemphasize the recommendation that policy decisions should focus on 5-year averages as ‘current’ data and on multi-year trends.

Current levels for the Netherlands (2005-2009)

Because of occasional years of low sample size (e.g. 2008) and incidental variability (e.g. 2009), it is strongly recommended to describe the ‘current pollution level’ on the basis of average stomach contents over the most recent 5 years. The 5-year period is also a standard element in the description of the OSPAR EcoQO (see below) Over the 2005-2009 period in a sample of 227 Northern Fulmars from the Dutch coast, plastic incidence was 95% with an average ± se number of 27.3 ± 2.5 pieces, and average mass of 0.29 ± 0.03 gram (details in Table 1b). This represents a slight improvement in comparison to the earlier 2004-2008 period (Table 3).

Trends in the Netherlands

Trends focus on the mass of plastics in stomachs, rather than on incidence or number of plastic particles. In trend discussions, a distinction is made between:

- 'long-term trend' which calculates the trend over all years in the dataset (now 1979-2009)
- 'recent trend' defined as trend over the past 10 years (now: 2000-2009)

Table 1 *Summary of sample characteristics and stomach contents of Fulmars collected for Dutch marine litter monitoring in a) the year 2009 and b) the current 5-year period 2005-2009. 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). Although only age is currently relevant in the Dutch dataset, this is not necessarily true in later international comparisons. 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 of plastic items per bird stomach ± standard error; average mass of plastic ± standard error 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-transformed values as used in trend-analyses.*

a) Year 2009

	YEAR	nr of birds	adult	male	LL colour	death oil	avg condition	
	2009	**68**	**40%**	**56%**	**63%**	**3%**	**1.1**	

		incidence	average number of items (n/bird)	± se	average mass of litter (g/bird)	± se	max. mass recorded	geometric mean mass (g/bird)
1	**ALL PLASTICS**	**97%**	**19.3**	**± 3.611**	**0.216**	**± 0.040**	**1.9**	**0.0835**
1.1	**INDUSTRIAL PLASTIC**	**46%**	**1.7**	**± 0.483**	**0.037**	**± 0.010**	**0.4**	**0.0050**
1.2	**USER PLASTIC**	**96%**	**17.6**	**± 3.203**	**0.179**	**± 0.035**	**1.8**	**0.0641**
1.2.1	sheets	44%	1.8	± 0.426	0.024	± 0.012	0.8	0.0019
1.2.2	threads	40%	0.8	± 0.168	0.031	± 0.017	1.1	0.0016
1.2.3	foamed	66%	4.9	± 1.252	0.017	± 0.004	0.2	0.0032
1.2.4	fragments	88%	9.8	± 1.999	0.102	± 0.020	1.0	0.0293
1.2.5	other plastic	9%	0.2	± 0.071	0.006	± 0.003	0.2	0.0003
2	**OTHER RUBBISH**	**41%**	**1.7**	**± 0.463**	**0.144**	**± 0.070**	**4.0**	**0.0043**
2.1	paper	3%	0.0	± 0.021	0.011	± 0.010	0.7	0.0002
2.2	kitchenwaste (food)	40%	1.7	± 0.464	0.132	± 0.069	4.0	0.0037
2.3	rubbish various	0%	0.0	± 0.000	0.000	± 0.000	0.0	0.0000
2.4	fishhook	0%	0.0	± 0.000	0.000	± 0.000	0.0	0.0000

b) current 5-year period (2005-2009)

	YEAR	nr of birds	adult	male	LL colour	death oil	avg condition	
	2005-2009	**227**	**51%**	**49%**	**83%**	**4%**	**1.3**	

		incidence	average number of items (n/bird)	± se	average mass of litter (g/bird)	± se	max. mass recorded	geometric mean mass (g/bird)
1.0	**ALL PLASTICS**	**95%**	**27.3**	**± 2.495**	**0.288**	**± 0.026**	**2.4**	**0.1022**
1.1	**INDUSTRIAL PLASTIC**	**59%**	**2.6**	**± 0.270**	**0.057**	**± 0.006**	**0.5**	**0.0106**
1.2	**USER PLASTIC**	**94%**	**24.8**	**± 2.342**	**0.231**	**± 0.023**	**2.2**	**0.0751**
1.2.1	sheets	52%	2.8	± 0.351	0.013	± 0.004	0.8	0.0019
1.2.2	threads	42%	1.3	± 0.205	0.021	± 0.007	1.1	0.0016
1.2.3	foamed	67%	5.8	± 0.796	0.018	± 0.003	0.3	0.0034
1.2.4	fragments	88%	14.3	± 1.548	0.159	± 0.019	2.1	0.0427
1.2.5	other plastic	19%	0.5	± 0.162	0.019	± 0.006	1.2	0.0011
2.0	**OTHER RUBBISH**	**34%**	**2.2**	**± 0.586**	**0.079**	**± 0.023**	**4.0**	**0.0028**
2.1	paper	2%	0.0	± 0.012	0.004	± 0.003	0.7	0.0001
2.2	kitchenwaste (food)	26%	2.0	± 0.547	0.063	± 0.022	4.0	0.0018
2.3	rubbish various	9%	0.2	± 0.059	0.012	± 0.005	1.0	0.0004
2.4	fishhook	0%	0.0	± 0.000	0.000	± 0.000	0.0	0.0000

Table 2a ***Annual details for plastic abundance in Fulmars from the Netherlands.*** *For separate and combined plastic categories, incidence (%) represents the proportion of birds with one or more items of that litter present; number (n) abundance by average number of items per bird; and mass (g) abundance by average mass per bird in grams. The column on the far right indicates level of performance in relation to the OSPAR EcoQO, viz. the percentage of birds having more than the critical level of 0.1 gram of plastic in the stomach. The bottom line of the table shows the 'current' situation as the average over the past 5 years. 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 erratic variability in age proportions of birds in samples, where age is known to influence amount of litter in the stomach. Trend analyses (table 4) are not based on annual averages, but on values from all individual birds, together and in age-groups, to overcome problems of years of poor sample size or variable age composition.*

			INDUSTRIAL PLASTICS			USER PLASTICS			ALL PLASTICS (industrial + user)			EcoQO
YEAR	*n*	% adult	%	n	g	%	n	g	%	n	g	> 0.1 g
1979	*1*	0%	100%	2.0	0.07	100%	3.0	0.17	100%	5.0	0.24	100%
1980												
1981												
1982	*3*	0%	100%	5.0	0.11	67%	6.0	0.50	100%	11.0	0.61	100%
1983	***19***	**41%**	**84%**	**8.8**	**0.19**	**89%**	**7.2**	**0.31**	**100%**	**16.0**	**0.49**	**89%**
1984	***20***	**40%**	**70%**	**9.6**	**0.19**	**90%**	**8.4**	**0.17**	**90%**	**17.9**	**0.35**	**55%**
1985	*3*	33%	100%	5.3	0.14	100%	5.0	0.14	100%	10.3	0.28	100%
1986	*4*	25%	50%	0.8	0.02	75%	4.8	0.06	75%	5.5	0.08	25%
1987	***15***	**67%**	**80%**	**3.9**	**0.11**	**67%**	**8.9**	**0.09**	**80%**	**12.7**	**0.20**	**53%**
1988	*1*	0%	0%	0.0	0.00	100%	2.0	0.04	100%	2.0	0.04	0%
1989	*4*	50%	75%	5.3	0.14	100%	11.0	0.16	100%	16.3	0.29	75%
1990												
1991	*1*	0%	0%	0.0	0.00	100%	11.0	0.14	100%	11.0	0.14	100%
1992												
1993												
1994												
1995	*2*	50%	100%	1.5	0.02	100%	3.5	0.03	100%	5.0	0.06	0%
1996	*8*	63%	75%	2.9	0.07	100%	24.5	0.19	100%	27.4	0.26	63%
1997	***31***	**16%**	**74%**	**5.9**	**0.13**	**97%**	**29.8**	**0.60**	**97%**	**35.8**	**0.73**	**84%**
1998	***74***	**45%**	**69%**	**3.1**	**0.07**	**95%**	**25.9**	**0.88**	**96%**	**29.0**	**0.95**	**72%**
1999	***107***	**70%**	**58%**	**3.4**	**0.06**	**97%**	**31.8**	**0.38**	**98%**	**35.3**	**0.44**	**61%**
2000	***38***	**58%**	**61%**	**3.4**	**0.08**	**100%**	**18.6**	**0.27**	**100%**	**22.0**	**0.35**	**61%**
2001	***54***	**38%**	**63%**	**2.6**	**0.06**	**96%**	**20.4**	**0.18**	**96%**	**22.9**	**0.24**	**48%**
2002	***56***	**54%**	**68%**	**4.6**	**0.09**	**96%**	**47.2**	**0.41**	**98%**	**51.8**	**0.50**	**68%**
2003	***39***	**56%**	**51%**	**2.3**	**0.05**	**92%**	**26.3**	**0.12**	**95%**	**28.5**	**0.17**	**54%**
2004	***131***	**80%**	**54%**	**2.6**	**0.06**	**91%**	**20.8**	**0.22**	**91%**	**23.4**	**0.27**	**60%**
2005	***51***	**68%**	**53%**	**2.0**	**0.05**	**96%**	**15.8**	**0.22**	**98%**	**17.8**	**0.27**	**47%**
2006	***27***	**62%**	**78%**	**3.5**	**0.08**	**93%**	**30.4**	**0.23**	**93%**	**33.9**	**0.30**	**85%**
2007	***61***	**42%**	**70%**	**3.1**	**0.07**	**90%**	**32.5**	**0.30**	**92%**	**35.6**	**0.37**	**70%**
2008	***20***	**58%**	**65%**	**3.8**	**0.08**	**95%**	**40.8**	**0.23**	**95%**	**44.5**	**0.31**	**55%**
2009	***68***	**40%**	**46%**	**1.7**	**0.04**	**96%**	**17.6**	**0.18**	**97%**	**19.3**	**0.22**	**46%**
2005-2009	***227***	**51%**	**59%**	**2.6**	**0.06**	**94%**	**24.8**	**0.23**	**95%**	**27.3**	**0.29**	**58%**

* Five-year data w ere averaged over all individual birds in the five year period (so not from annual averages)

Long- and short term changes are quantified in tables 2a and 3, and visualised in Fig's 1 and 2, which compare a single overall average figure for the 1980's to running 5-year averages for plastic mass in stomachs of Fulmars from the Dutch coast since the mid-1990s. Statistical tests for significance of trends are based on linear regressions of ln-transformed data for the mass of plastics against year of collection in individual stomachs (Table 4).

Long term trend 1979-2009

In spite of evident strong changes in Fig.1, the 'all plastics' category shows no clear long term linear trend (Table 4A). This has several reasons. Firstly, the overall mass of plastics strongly increased from the 1980s to the 1990s but has subsequently decreased to approximately the initial level. Linear analyses do not 'see' the variable components in non-linear trends. But calculations are also compromised because different types of plastic have shown strongly different trends (Fig. 2). User plastics were responsible for the above described increase and later decrease. Industrial plastics on the other hand have strongly decreased since the early 1980s, resulting in a highly significant long-term reduction ($p<0.001$). As a consequence of these mixed trends, the composition of plastic litter has strongly changed since the early 1980s, with nowadays a reduced proportion of industrial plastics (reduced from about 50% to circa 20% of total mass) and an increased mass of user plastics from discarded waste (Tables 1 and 2). Decreases in industrial plastics have also been observed in other parts of the world (Vlietstra & Parga 2002; Ryan 2008; Ryan et al. 2009)

Table 2b ***Details for plastic abundance in stomachs of Fulmars from the Netherlands 2009*** *with data compared for birds found during the sudden influx in January to those found during the remainder of the year. See Table 2a for explanations.*

			INDUSTRIAL PLASTICS			USER PLASTICS			ALL PLASTICS (industrial + user)			EcoQO
2009	*n*	% adult	%	n	g	%	n	g	%	n	g	> 0.1 g
January	***46***	**48%**	**35%**	**0.9**	**0.02**	**98%**	**12.0**	**0.13**	**100%**	**12.8**	**0.15**	**41%**
Feb-Dec	***22***	**23%**	**68%**	**3.5**	**0.08**	**91%**	**29.3**	**0.28**	**91%**	**32.7**	**0.36**	**55%**

Table 3 ***Incidence, number of particles and mass of plastics in stomachs of fulmars beached in the Netherlands in the 1980's and 'running' 5-year periods since 1995****. Mass data are also shown as geometric mean mass, and as percentage of stomachs with more than 0.1 gram of plastic (EcoQO performance).*

ALL AGES **5-year period**	***sample n***	**Incidence %**	**average number n ± se**		**average mass g ± se**		**geometric mean mass (g)**	**Over 0.1 g EcoQO %**
1980s	*69*	91%	14.6	± 2.0	0.34	± 0.06	0.11	67%
1995-1999	*222*	97%	32.7	± 3.7	0.64	± 0.13	0.15	67%
1996-2000	*258*	98%	31.3	± 3.2	0.60	± 0.12	0.15	67%
1997-2001	*304*	97%	29.9	± 2.8	0.55	± 0.10	0.14	63%
1998-2002	*329*	98%	33.1	± 3.3	0.52	± 0.10	0.13	62%
1999-2003	*294*	98%	33.5	± 3.6	0.37	± 0.06	0.11	59%
2000-2004	*318*	95%	28.8	± 2.9	0.30	± 0.04	0.09	59%
2001-2005	*331*	95%	27.9	± 2.7	0.29	± 0.04	0.09	57%
2002-2006	*304*	94%	29.3	± 3.0	0.30	± 0.04	0.09	61%
2003-2007	*309*	93%	26.5	± 2.1	0.28	± 0.02	0.09	61%
2004-2008	*290*	93%	27.4	± 2.2	0.30	± 0.03	0.10	62%
2005-2009	*227*	95%	27.3	± 2.5	0.29	± 0.03	0.10	58%

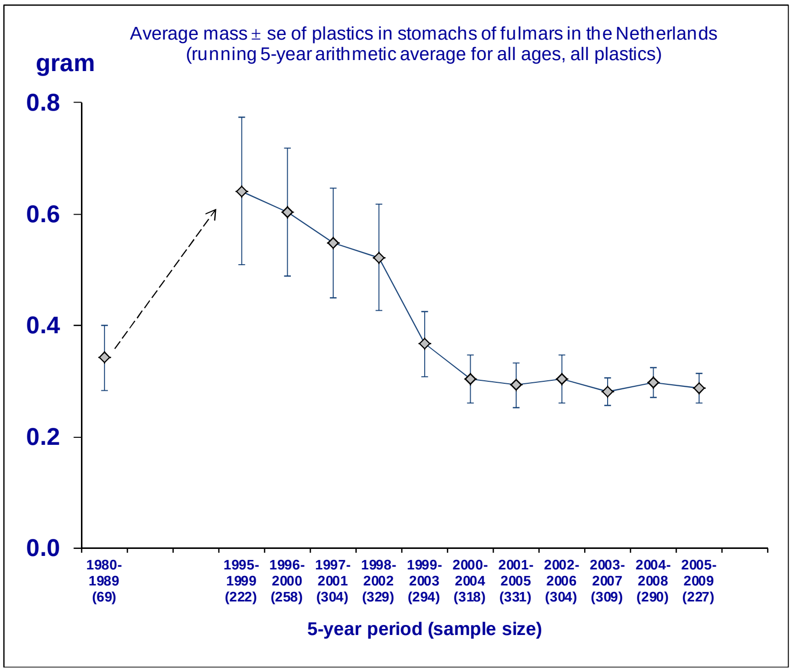


Figure 1 ***Plastic mass in Fulmars from the Netherlands 1982-2009.*** *The trend in 5 year averages for mass of plastic in stomachs of Fulmars beached in the Netherlands (running average over 5 year periods, i.e. data points shift one year ahead at a time; x-axis labels show 5-year periods and in brackets the sample-sizes).*

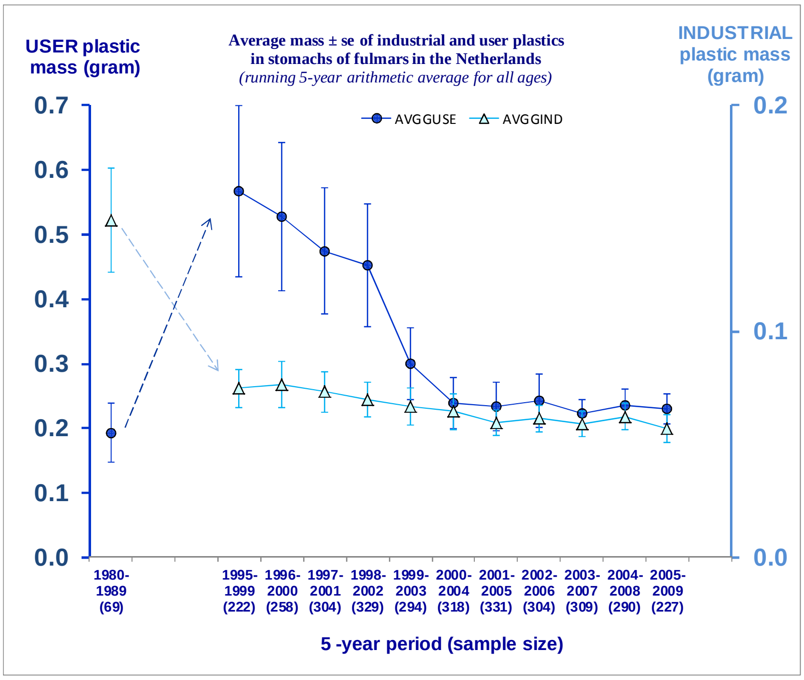


Figure 2 ***Trends of industrial and user plastic in Fulmars from the Netherlands 1982-2009.*** *The trend in 5 year averages for mass of plastic in stomachs of Fulmars beached in the Netherlands (running average over 5 year periods, i.e. data points shift one year ahead at time; x-axis labels show 5-year periods and in brackets the sample-sizes).*

Table 4 ***Details of linear regression analyses for time related trends in plastic abundance in stomachs of fulmars in the Netherlands***. *Analysis by linear regression, fitting ln-transformed litter mass values for individual birds on the year of collection. Tests were conducted over the full time period 1979-2009 (Table 4A) and the most recent 10 years of data (Table 4B). The regression line ('trend') is described by y = Constant + estimate*x in which y is the calculated value of the regression-line for year x. When the t-value of a regression is negative it indicates a decreasing trend in the tested litter-category; a positive t-value indicates increase. A trend is considered significant when the probability (p) of misjudgement of data is less than 5% (p<0.05). Significant trends in the table have been labelled with positive signs in case of increase (+) or negative signs in case of decrease (-). Significance at the 5% level (p<0.05) is labelled as - or + ; at the 1% level (p<0.01) as -- or ++; and at the 0.1% level (p<0.001) as --- or +++.*

A.	**LONG TERM TRENDS 1979-2009**						
	for plastics in Fulmar stomachs, the Netherlands						
INDUSTRIAL PLASTIC (lnGIND)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*838*	113.5	-0.0588	0.0124	-4.76	<0.001	- - -
adults	*456*	80.1	-0.0423	0.0190	-2.22	0.027	-
non adults	*369*	122.0	-0.0629	0.0163	-3.85	<0.001	- - -
USER PLASTICS (lnGUSE)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*838*	-26.4	0.0119	0.0106	1.12	0.263	*n.s.*
adults	*456*	-11.4	0.0043	0.0170	0.25	0.801	*n.s.*
non adults	*369*	-52.2	0.0250	0.0133	1.87	0.062	*n.s.*
ALL PLASTICS COMBINED (lnGPLA)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*838*	33.4	-0.0178	0.0103	-1.73	0.084	*n.s.*
adults	*456*	19.7	-0.0111	0.0168	-0.66	0.510	*n.s.*
non adults	*369*	27.6	-0.0147	0.0124	-1.19	0.234	*n.s.*

B.	**RECENT 10-year TRENDS (2000-2009)**						
	for plastics in Fulmar stomachs, the Netherlands						
INDUSTRIAL PLASTIC (lnGIND)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*545*	57.6	-0.0309	0.0346	-0.89	0.372	*n.s.*
adults	*309*	118.0	-0.0613	0.0507	-1.21	0.227	*n.s.*
non adults	*226*	49.5	-0.0268	0.0477	-0.56	0.575	*n.s.*
USER PLASTICS (lnGUSE)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*545*	-2.1	-0.0003	0.0289	-0.01	0.992	*n.s.*
adults	*309*	9.5	-0.0062	0.0457	-0.14	0.892	*n.s.*
non adults	*226*	36.1	-0.0191	0.0341	-0.56	0.575	*n.s.*
ALL PLASTICS COMBINED (lnGPLA)	***n***	**Constant**	**estimate**	**s.e.**	**t**	**p**	
all ages	*545*	21.6	-0.0119	0.0285	-0.42	0.676	*n.s.*
adults	*309*	34.3	-0.0184	0.0450	-0.41	0.684	*n.s.*
non adults	*226*	59.6	-0.0307	0.0335	-0.92	0.360	*n.s.*

Recent 10-year trend 2000-2009

Until 2006, regression analyses for 10-year trends showed significant decreases in litter since the mid 1990's, mainly due to decreases in user plastics (Fig. 2). However, in the analyses for later periods no significant changes were observed. From Fig. 2 it is clear that since the turn of the century, changes in both industrial and user plastics have been relatively minor. Fortunately the 2000-2009 analyses for trends do suggest continued decreases for both user and industrial plastic in Dutch Fulmars (signs of t values in table 4B all negative) but at an extremely low rate and not at a statistically relevant level.

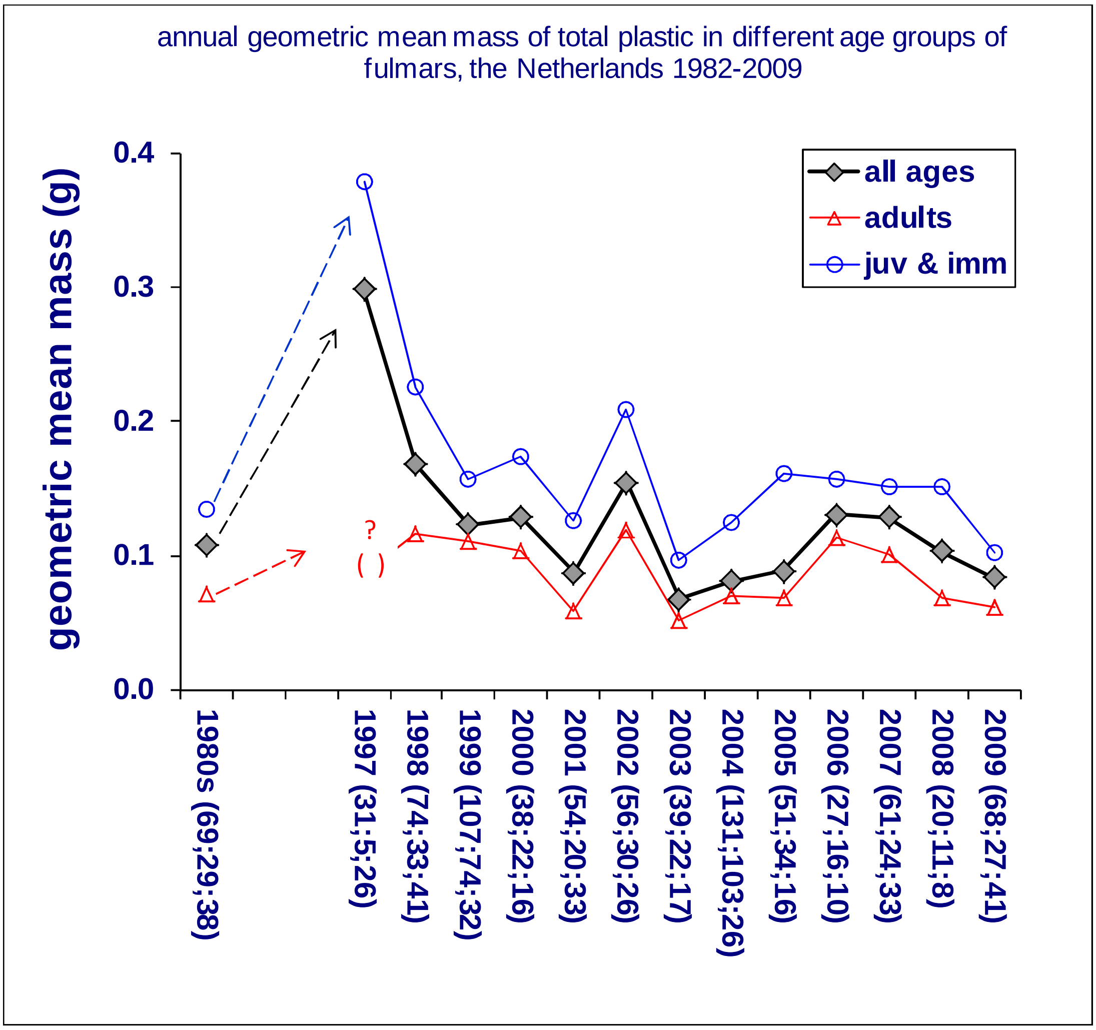


Figure 3 ***Annual geometric means for mass of plastics in stomachs of beached Fulmars*** *from the Netherlands 1982-2009 for all age groups combined (including birds of unknown age), adult birds and non-adults, with sample sizes in brackets in the x-axis labels. Data illustrate the trends and consistency in age-differences that allow usage of the all-age trend-line in the summary.*

Annual data: geometric means

As explained in methods, the statistical tests (Table 4) for trends over time do not use annual or multi-year averages, but are based on stomach contents data from individual birds and year of collection. This allows greater detail and the inclusion of data from years where only small samples of birds were collected. Values for plastic contents are logarithmically transformed, because data are not normally distributed with a few high values obscuring trend analysis. Logarithmic transformation normalizes the distribution of data and reduces the influence of the exceptionally high values.

However, annual figures are more convenient for regular annual updates in a monitoring program and since 1997 the Dutch annual sample sizes have usually been large enough to calculate annual means.

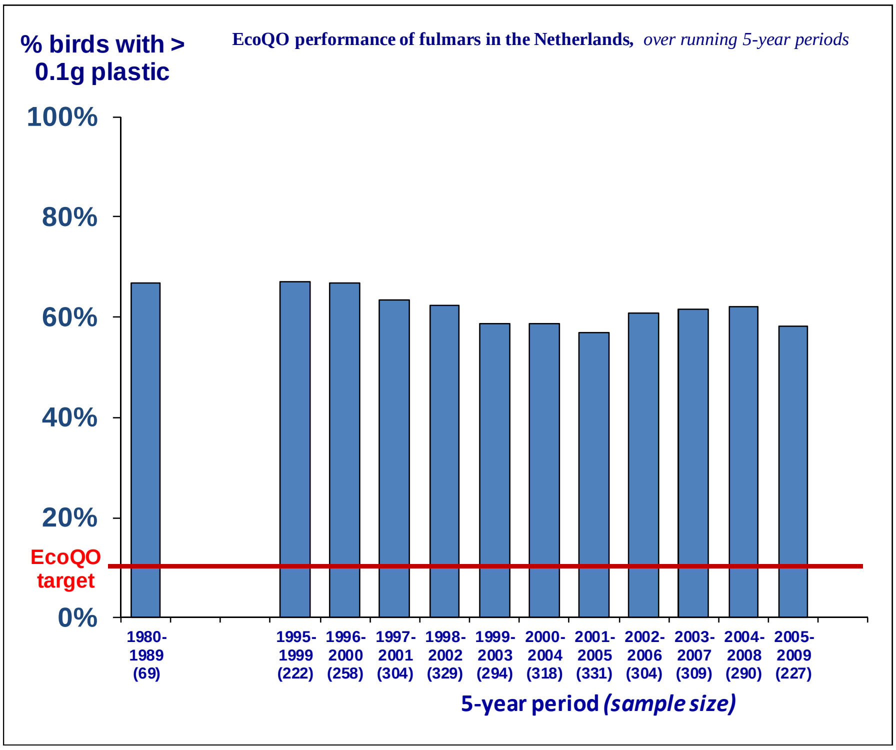
Logarithmic transformation of data is still needed, but the average of logarithmic values can be transformed back into a 'normal' value, which is then known as the 'geometric mean'. Geometric means are appropriate to make comparisons between groups of samples (years, but also regions), but it has to be kept in mind that they can be very different from normal averages ('arithmetic means'). Since logarithmic transformation reduces the role of higher values, the geometric mean is usually considerably lower than the arithmetic mean for the same data. In mass data for plastics in the Fulmar stomachs, geometric means are only about one third of the arithmetic means (see Table's 1 and 3).

Annual geometric means for total plastic mass in the Fulmar stomachs since 1997 and the combined figure for the early 1982-1990 period are shown in Fig. 3. The graph illustrates the trends calculated in Table 4. As mentioned before, the 2009 geometric data suggest that a decrease in 2009 levels is not only caused by the influx of northern birds in the January wreck because reductions are especially visible in the non-adult category that dominated in the samples later in the year. Anyhow, it can be seen that the slight increases that were feared from data from 2003 to 2007 are not persistent, and that data after 2007 now indicate slow decreases in pollution levels. The geometric mean data again reconfirm that patterns for different age groups follow a similar trend, allowing use of integrated data over all age-groups for monitoring.

Dutch data in terms of the OSPAR EcoQO metric

ICES working groups, followed by OSPAR, have always described the EcoQO metric for marine litter in terms of a percentage of birds exceeding a critical value of plastic in the stomach. At first sight, one might argue that it would be easier to use an EcoQO definition based on for example only the average mass of plastics. However, whether intentional or not, the 'percentage plus critical value' definition represents a sort of simplified procedure that avoids the mathematical problems caused by a few excessive stomach contents distorting comparative analyses. In the testing procedures and geometric means used above, such problems are overcome by logarithmic transformation of data. And although this is a standard statistical procedure, it is not always easily conveyed to the general public, and differences between means (arithmetic versus geometric) can be confusing. The EcoQO metric avoids such problems by using classes of birds in which the exceptional stomach contents lose their influence. Currently, the target for acceptable ecological quality has been defined as the situation in which *"less than 10% of northern fulmars (Fulmarus glacialis) have more than 0.1 gram plastic particles in the stomach in samples of 50 to 100 beach-washed fulmars from each of 4 to 5 different areas of the North Sea over a period of at least 5 years".* So in such a definition an excessive stomach content of e.g. 10 gram of plastic does not change the metric compared to the situation in which that bird would have had for example only 0.2 g in its stomach.

Using the same data as in earlier sections of this report, Figure 4 shows the time trends in the 5-year average EcoQO performance of Fulmars found in the Netherlands. With the Y-axis scaled to a 100% range (top graph), the distance from the 10% EcoQO target set by OSPAR is strongly visualised and emphasizes the need for further improvement. At this axis scale the graph insufficiently shows the changes since the mid 1990's. The same data at a finer scale can be seen in Fig. 4 bottom graph showing gradual improvements in EcoQO performance from 67% down to 57% exceeding 0.1g level in the 2001-2005 period. Small increases in the following periods were of concern, but geometric means and current EcoQO data, in combination with the 10-year trend tested in Table 4, do indicate decreases, albeit at extremely slow and insignificant rate. The low 46% EcoQO figure for just year 2009 (Table 2a) is expected to be biased because of the January wreck of recently arrived northern birds. Over the integrated 5-year period 2005-2009, 58% of Dutch Fulmars exceeds the 0.1g critical EcoQO level, which is still far off the 10% target, but second best in all historical data for the Netherlands.



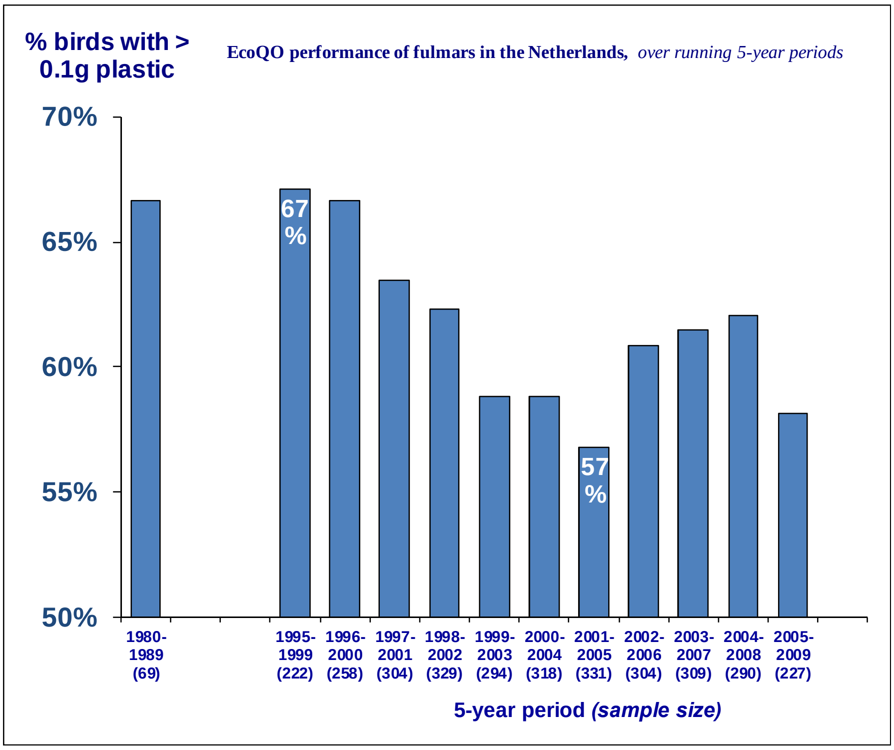


Figure 4 ***EcoQO performance of fulmars in the Netherlands*** *over running 5-year periods (single average for 1980s); the upper and lower graphs show the same data, but lower one gives higher detail. The OSPAR EcoQO target is to reduce the percentage of birds with more than 0.1g of plastic in the stomach to below 10%*

5.2. Monitoring data in the North Sea

As convened in OSPAR (2008), study areas in the North Sea are grouped into 5 regions, that is the Scottish Islands (Shetland and Orkney), East England (north- and southeast), Channel (Normandy and Pas de Calais), South-Eastern North Sea (Belgium, Netherlands and Germany), and the Skagerrak (Skagen Denmark, Lista Norway and Swedish west coast).

Earlier integrated North Sea wide EcoQO reports discussed the period 2002-2004 (Van Franeker et al. 2005), later extended up to 2006 (Van Franeker & the SNS Fulmar Study Group 2008) and up to 2007 (Van Franeker et al. *in press 2011*). In addition to the Dutch monitoring program, the international reports were funded by EU Interreg IIIB and the NYK Group Europe Ltd. Data for the Faroe Islands have been collected with assistance from Chevron Upstream Europe. The current update up to year 2009 became possible because of additional funding in the DGLM update for 2009. Norway financed a 2008 update of its country, and the UK currently funds 2008-2009-2010 analyses of its North Sea samples.

In line with earlier analyses there appears to be a consistent regional pattern, in which highest plastic abundance is seen in Fulmars from the Channel, with gradually decreasing levels further to the north both along western and eastern shores of the North Sea. During 2005-2009 (Table 5, Figure 5), as in the first SNS report, geometric mean mass of plastics in Fulmars in the Channel area (0.27g) are over four times the level observed in birds from the Faroe Islands (0.06g). Regional differences within the North Sea seem slightly less pronounced than before, in which Fulmar stomachs from East England seem to become more polluted and the birds from the SE North Sea somewhat less polluted than in earlier periods. However, details are not fully consistent when data are looked at as arithmetic average mass, geometric mean mass or EcoQO% (Fig.5 A,B,C). Considering the still relatively short period of sampling and often low annual sample sizes in several of the North Sea regions, it is not yet possible to properly analyse the trends over time in the different regions. Nevertheless, Fig 6 provides a preliminary view on regional trends and suggests stability in the SE North Sea and light to moderate increases in the other regions. Linear regressions for all age groups combined suggested increase for the Scottish Islands and the Channel area to be significant, but tests do not hold, or are sometimes even opposite for different age groups, indicating influences of unequal sample effort and age composition in samples. Continued monitoring will be needed to confirm trends as suggested in Fig. 6.

Table 5 ***Incidence, number of particles and mass of plastics in stomachs of fulmars beached in different North Sea regions during the 5-year period 2005-2009****. Mass data also shown as geometric mean mass, and as percentage of stomachs with more than 0.1 gram of plastic (EcoQO performance)*

		Incidence	average number		average mass		geometric	Over 0.1 g
REGION	***n***	**%**	**n ± se**		**g ± se**		**mean mass (g)**	**EcoQO %**
Scottish Islands	*108*	91%	23.7	± 3.6	0.36	± 0.07	0.09	59%
East England	*52*	98%	46.5	± 6.4	0.36	± 0.06	0.16	77%
Channel area	*74*	99%	50.5	± 9.1	0.53	± 0.08	0.27	86%
SE North Sea	*602*	95%	23.9	± 1.4	0.30	± 0.03	0.10	57%
Skagerrak area	*80*	98%	53.5	± 15.4	0.31	± 0.05	0.10	53%
North Sea total	*916*	95%	29.9	± 1.9	0.33	± 0.02	0.11	60%
Faroe Islands	*371*	91%	15.1	± 1.6	0.21	± 0.02	0.06	46%
Canadian Arctic 2002-08	*169*	40%	2.5		0.03			14%

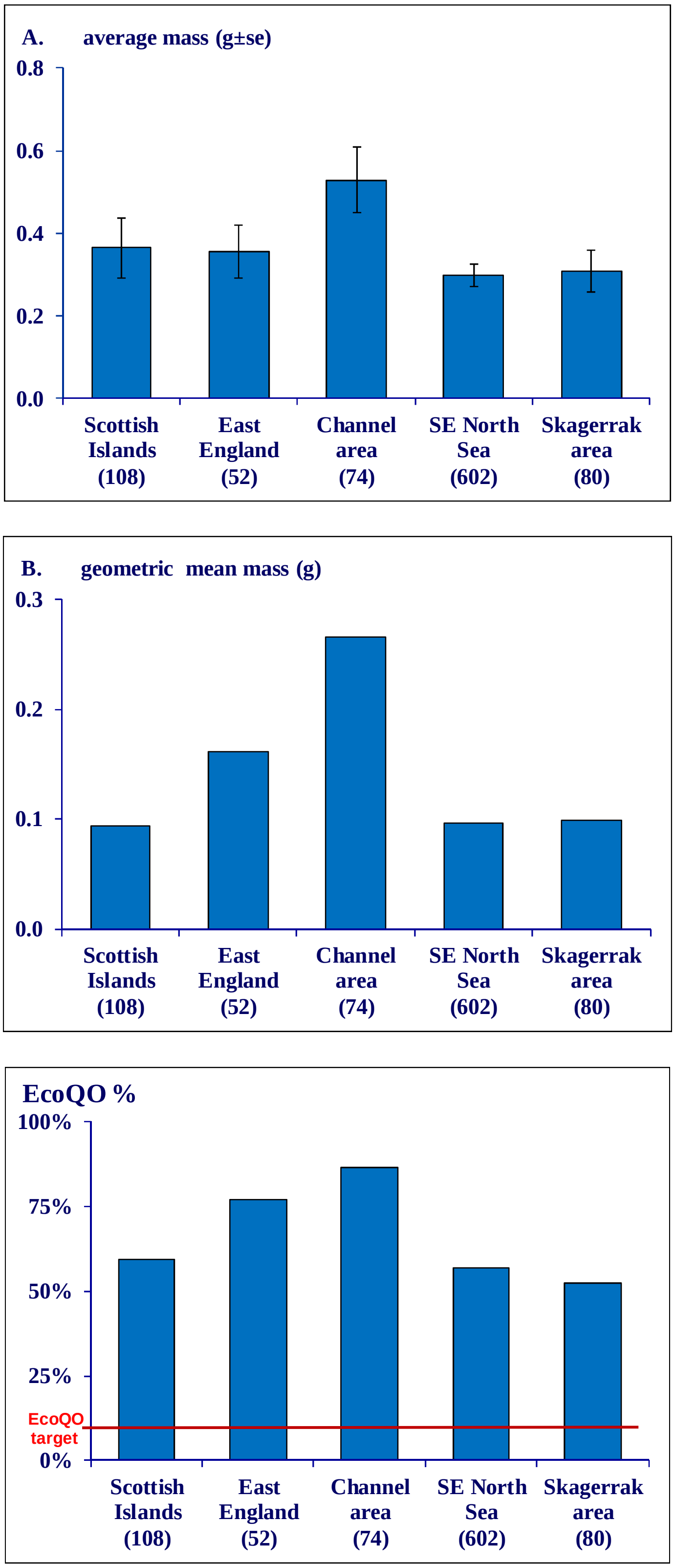


Figure 5 ***Regional variation in average plastic mass in fulmar stomachs in the North Sea regions 2005-2009*** ***A***: *arithmetic average ± se;* ***B***: *geometric mean mass, and* ***C***: *in EcoQO performance (% of birds with > 0.1g plastic)*

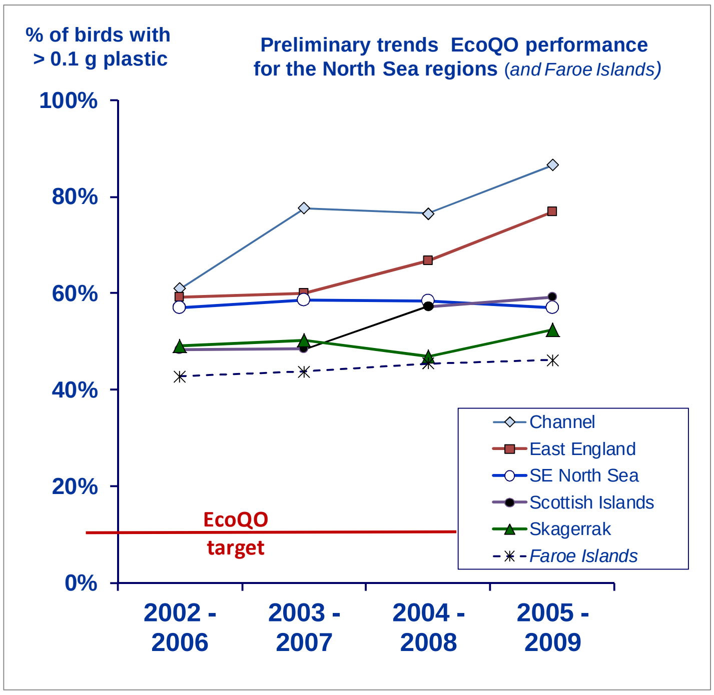


Figure 6 Trends in EcoQO performance in different regions of the North Sea since 2002 *(by running 5-year average data).*

Whatever the details on regional differences and trends, it is clear that nowhere in the North Sea the OSPAR EcoQO target of a maximum of 10% of birds exceeding 0.1g plastic in the stomach, is reached. During 2005-2009, EcoQO performance within the North Sea ranged from 53% (Skagerrak) to 86% (Channel). When moving out of the North Sea, fulmar stomachs are cleaner at the Faroe Islands (46% EcoQO performance), and only approach the target in the Canadian Arctic (Table 5 and Figure 7, Canadian data compiled from Mallory et al. 2006, Mallory, 2008, and Provencher et al. 2009 and personal information from the authors). Probably the situation within the Canadian arctic does comply with the OSPAR EcoQO target for the North Sea, but the measured level is somewhat biased by birds that had recently migrated into the area returning from more polluted wintering areas (Van Franeker *et al. in press 2011)*.

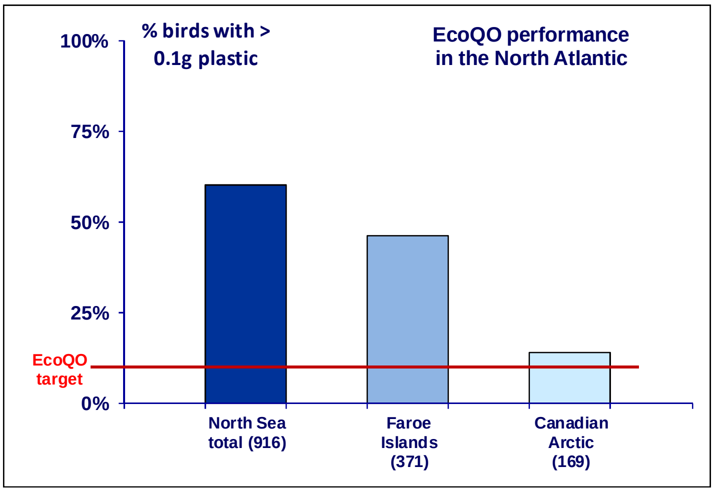


Figure 7 North Sea EcoQO performance (2005-2009), compared to more northern areas.

5.3. Exploring details in North Sea data: patterns and sources

Van Franeker et al. (2005) surveyed data from the 2002-2004 SNS study for details beyond the basic plastic monitoring required for the OSPAR EcoQO. Splitting up data for separate locations and subcategories of materials reduces statistical robustness because of smaller samples and local variations, but can nevertheless be indicative for certain important elements. The earlier analyses provided more insight into patterns and sources of marine debris in the North Sea, in particular on the potential role of shipping.

The regional pattern of marine litter that was shown in Fig.5 is repeated for the separate study locations during the 2005-2009 period in Figure 8. Locations SE England, Pas de Calais and Sweden were omitted because the samples from those locations were single events only in 2003 or 2004. The 2005-09 results support the 2002-04 conclusion on high pollution in the Channel area, gradually decreasing to the north. High pollution levels along the north east England coast, uncertain in Van Franeker et al 2005, are confirmed. Belgian and Dutch pollution levels appear relatively low compared to the Channel and other areas. This fits the pattern seen in Fig.6 in which EcoQO performance in the SE North Sea appeared fairly stable whereas other regions tended to show increases in litter levels.

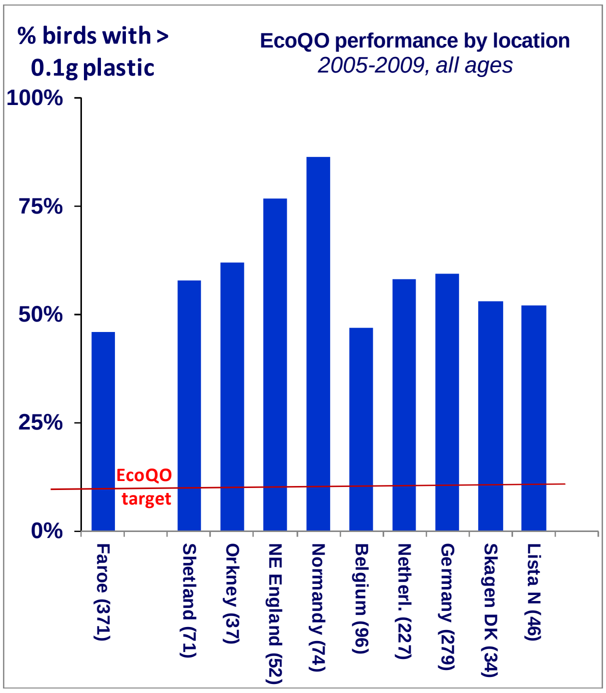


Figure 8 EcoQO performance (2005-2009) for all separate Fulmar study locations in the North Sea.

The residual currents in the European Atlantic are northwards through the Channel and around the UK mainland into the North Sea. The large difference in pollution between the Channel and Scottish Islands shows that a large proportion of North Sea marine litter is of local origin. If debris floating into Europe with Gulfstream waters was to blame, pollution to the north and south of UK would be much more similar. In addition, high levels of litter in Normandy, well before inflow of major river systems, suggest that that litter in the North Sea is linked to sea-based activities, in particular shipping, rather than to riverine inputs. As in 2005, the elevated levels of debris in stomachs of Fulmars around the Orkneys (average plastic mass 0.48 ± 0.16 g) as compared to those from the Shetlands (0.30 ± 0.07 g) may be considered to indicate shipping to be an important local source of marine litter, because shipping density around Orkney is about double that around the Shetlands. Major shipping activities in the European area are shown in Figure 9. A large detailed beach study on Texel, the Netherlands, in 2005 confirmed both conclusions i.e. that most debris has a local origin and is mainly linked to merchant shipping and fisheries (Van Franeker 2005).

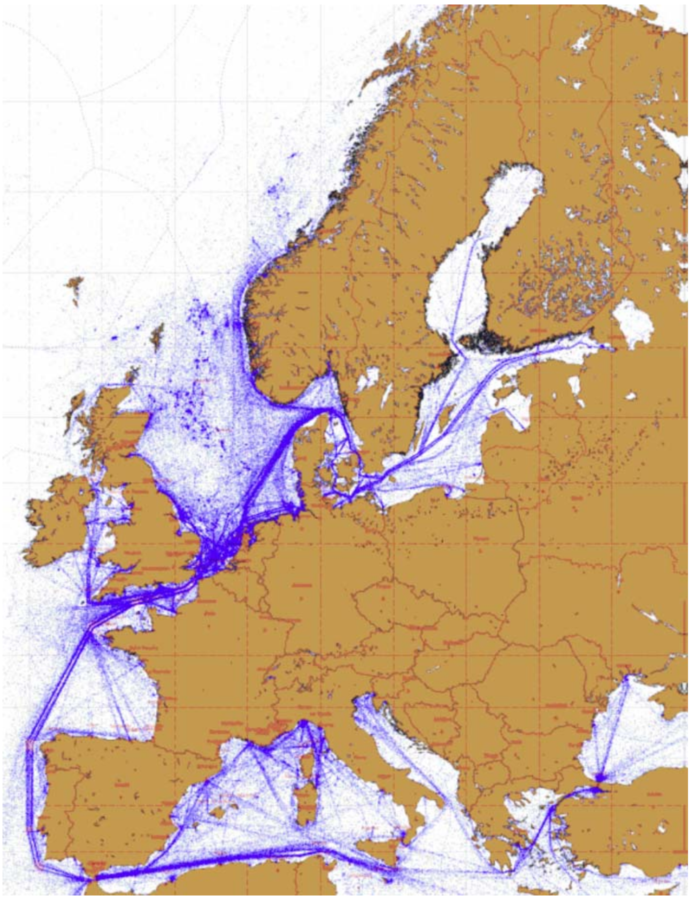


Figure 9 ***Shipping density in European waters (2002-2009),*** *by CLS, powered by SARTool, ENVISAT ASAR Products, European Space Agency ESA* *www.esa.int/esaEO/SEMBDI0OWUF_index_0.html*

There are additional approaches to assess the role of shipping, and it may of use to look at other litter types or plastic subcategories that could be indicative. Our category of 'non-plastic rubbish' is dominated by galley type food-remains which can be discharged legally by ships. Considering rates of degradation and likely sinking of materials, a land-based origin of such food-remains in fulmar stomachs must be considered unlikely. We consider presence of non-plastic rubbish in fulmar stomachs to be an indicator of foraging on ships wastes. Similarly we consider elevated abundance of foamed plastics to be indicative for immediate nearby sources at sea. Because of their extreme buoyancy, wind and waves will quickly displace foamed plastics, most pieces supposedly being beach-washed quickly onto shores. Figure 10 explores these two indicators for the different locations. Initial data surveys for the 2005-2009 period showed rather chaotic patterns which seemed to link to smaller samples with variable age compositions. Therefore, data for the full period of available data were used (start in 2002 or 2003 at most locations) and data-lines for different age groups have been added. Foamed plastics largely confirm earlier conclusions on peak densities of litter in the Channel and gradual reductions further north, indicating shipping as an important source of debris. Foamed plastic abundance in NE England also suggests pollution from ships at sea, but show an unusual age pattern indicating an instable sample, that shows even more strongly in the distribution pattern for non-plastic rubbish. However, other incidental events may be involved in this area, as remarkable incidents of large numbers of small plastics are increasingly reported here (Turner, 2011). Differences in patterns for industrial and user plastics in Van Franeker et al. (2005; Fig 14), suggested then that industrial plastics could be more from riverine sources. Such a conclusion cannot be confirmed with the current data. Peak abundances of industrial plastics are now seen in samples from the Channel and NE England, in the same samples where user plastics are most common (Fig.11).

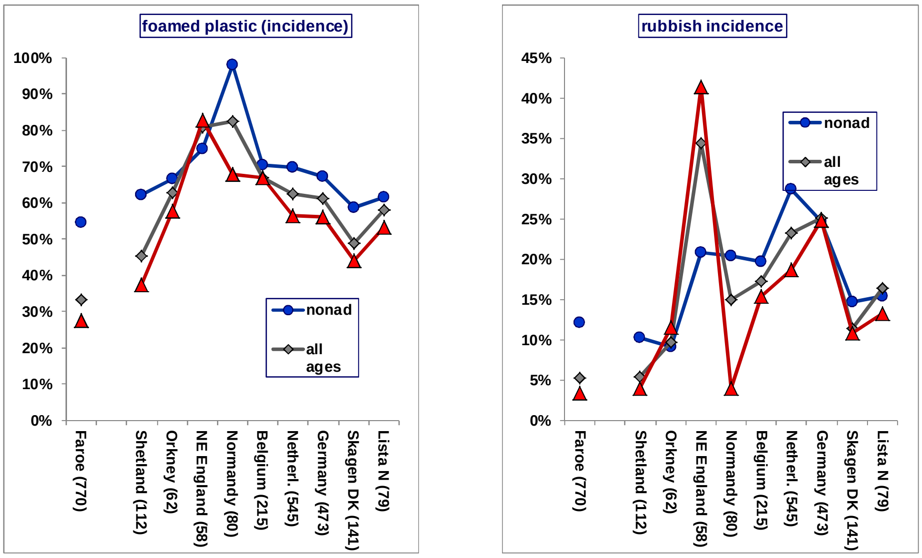


***Figure 10**. Incidence of non-plastic rubbish and foamed plastics in fulmar stomachs 2000-2009.*

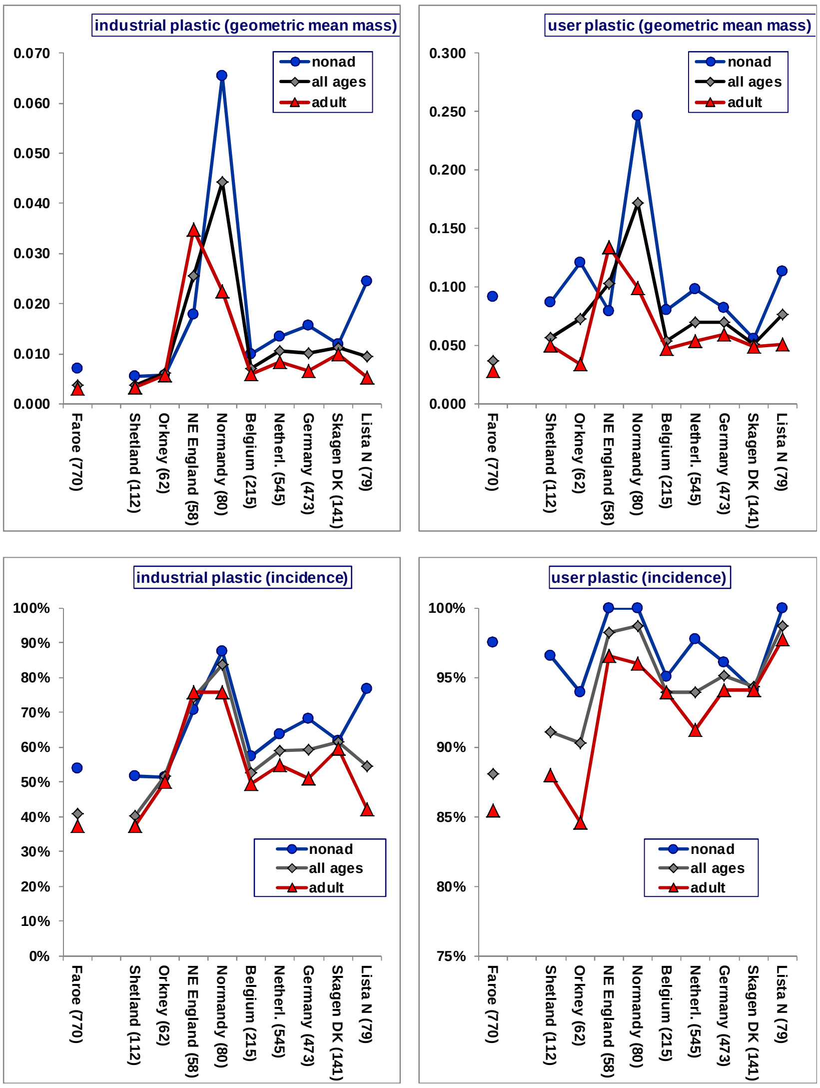


***Figure 11** Abundance of industrial and user plastic by mass and incidence in fulmar stomachs 2000-2009.*

Only for the Dutch data, a time trend in what we consider to be indicators for shipping as a source of marine debris can be looked at. Unlike the pattern for overall plastic mass in stomachs (Figs 1 and 2) in which decreases from the late 1990s halted in more recent years, the analysis for foamed plastics suggests continued decrease, which may suggest a decreasing role of shipping in/near the area, which could explain a relatively good performance (e.g. Figs 6 and 8) of fulmars from Belgium and the Netherlands. This could be a careful sign of the Directive on Port Reception Facilities and a reduced role of ships in litter abundance. This is not necessarily contradicted by fact that non-plastic rubbish, mainly galley wastes, is not showing a similar continued decrease. Delivery of food wastes is not a part of obligatory shore disposal, and in fact is discouraged by e.g. the Port of Rotterdam.

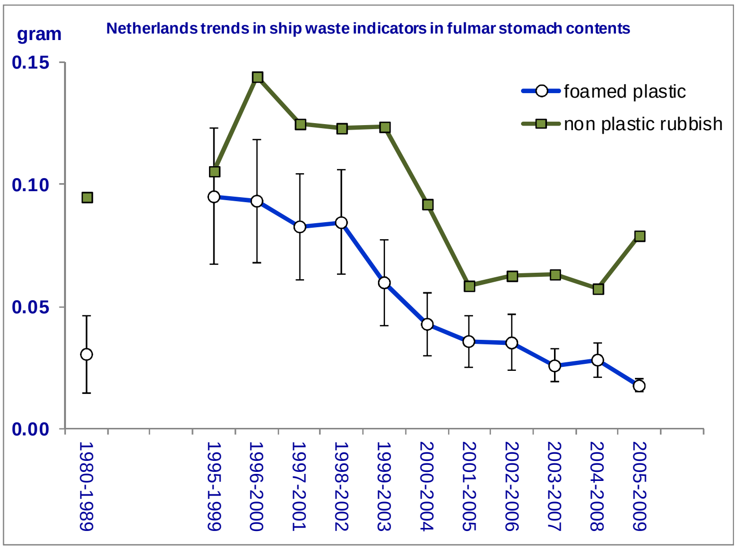


Figure 12 *Trends in abundance (average mass) of foamed plastics and non-plastic rubbish in Fulmars from the Netherlands, 1980-2009.*

At the detailed level of differences between locations and subcategories of litter, statistical significant conclusions are often hard to reach. Nevertheless, these detailed analyses do have a useful role in linking pollution to potential sources and thereby can contribute to appropriate management policies. So even when the OSPAR approach only requires regionally pooled data and a single plastic category, it will be useful to continue the current sampling scheme and detail of data recording as described in Chapter 4.2.

Even if there are some weak indications that the situation off the Dutch coast is improving, the EU Directive on Port Reception facilities has clearly not yet triggered the intended significant reduction in marine litter after its implementation in 2004. For unknown reasons, substantial improvement was achieved in years prior to the Directive. However, a proper evaluation must take into account that shipping and the use of plastic materials have strongly increased. Fig.13 shows trends in plastic production, shipping activity and the abundance of industrial and user plastics in stomachs of fulmars. It clearly shows that abundance of industrial plastics has been reduced while production and transport strongly increased. Ingested user plastics initially showed strong increases in line with shipping intensity and usage of plastic, improved considerably around the turn of the century and since then have stabilized in a period of continued growth of shipping and plastic production (except the 2008-09 crisis period). Even though the graphs in Fig.12 should not be viewed proportionally, they do indicate that lack of improvement not necessarily means that policy measures like various MARPOL regulations and the EU Directive on Port Reception Facilities are without effect (Trouwborst 2011).

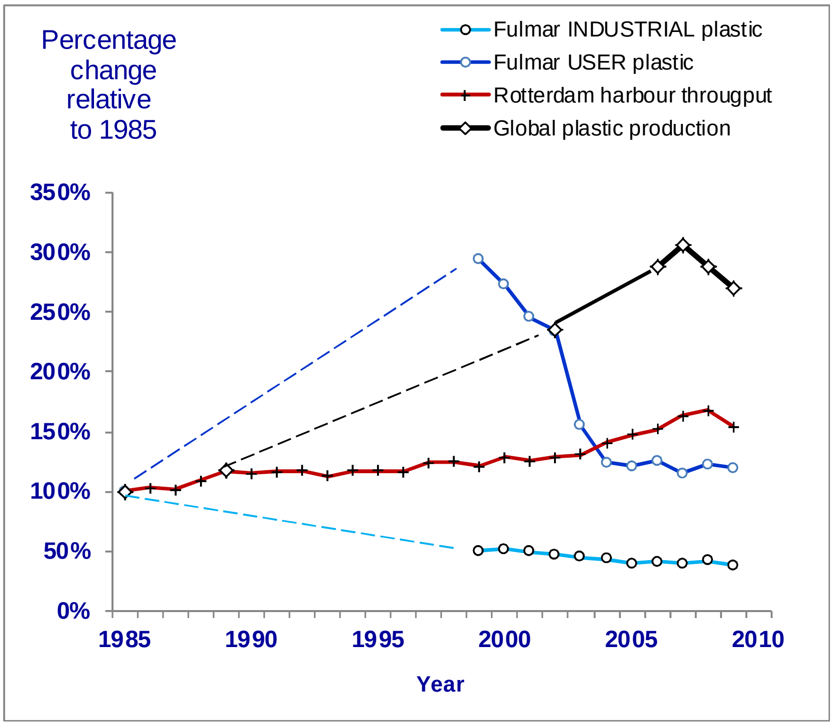


Figure 12 *Trends in global plastic production, freight quantities handled by Port of Rotterdam, and mass quantities of industrial and user plastics in stomachs of fulmars. Shown are cumulative percentage changes from reference year 1985.*

5.4. Conclusion

Stomach contents of Fulmars in the Netherlands indicate that the marine litter situation off the Dutch coast over the last decade is stable or very slowly improving. This appears to be the case for the SE North Sea in general, where other North Sea regions may still suffer slight increases of marine debris. However, all changes occur at insignificant rates. Shipping including fisheries is considered the major source of marine debris in our area. Implementation of the EC Directive on Port Reception Facilities thus may have stopped further deterioration in a period where potential sources of debris have increased, but has not resulted in the environmental improvement that it intended. Significant improvement of ecological quality is unlikely to be achieved without additional action.

6. Acknowledgements

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The SNS Fulmar Study Group consists of (with apologies to those not specifically named) Christine Blaize, Kees Camphuysen, Wouter Courtens, Maria Dam, Johannes Danielsen, Keith Fairclough, David Fleet, Jane Gollan, Gilles Le Guillou, Nils Guse, Poul-Lindhard Hansen, Martin Heubeck, Jens-Kjeld Jensen, Martin de Jong, Eric Meek, André Meijboom, Mick Mellor, Bergur Olsen, Kare-Olav Olsen, John Pedersen, Helle Schulz, Eric Stienen, Dan Turner and Marc van de Walle. Beached fulmars are mainly collected by volunteers, too many to be named individually, but without whom a project such as this is totally impossible. We are extremely grateful for their long-lasting support.

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Relevant websites

- http://www.imares.wur.nl/UK/research/dossiers/plastic/
- www.zeevogelgroep.nl *click on downloads – Fulmar-Litter-Study*

8. Quality Assurance

IMARES utilises an ISO 9001:2008 certified quality management system (certificate number: 57846-2009-AQ-NLD-RvA). This certificate is valid until 15 December 2012. The organisation has been certified since 27 February 2001. The certification was issued by DNV Certification B.V. Furthermore, the chemical laboratory of the Environmental Division has NEN-AND-ISO/IEC 17025:2005 accreditation for test laboratories with number L097. This accreditation is valid until 27 March 2013 and was first issued on 27 March 1997. Accreditation was granted by the Council for Accreditation.

9. Justification

Report C037/11
Project Number: 430.61164.01

The scientific quality of this report has been peer reviewed by a colleague scientist and the head of the department of IMARES.

Approved : F.C. Groenendijk MSc.
Research scientist

Signature:

Date: 4 July 2011

Approved: F.C. Groenendijk MSc.
Head of Department

Signature:

Date: 4 July 2011

Appendix I   Norway EcoQO report 2008

Fulmar Plastic EcoQO – Norway Update to 2008

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Project background

At the request of the North Sea ministers (2002), OSPAR, in cooperation with ICES, implements a system of ecological monitoring and targets for Ecological Quality Objectives (EcoQOs) in the North Sea. In relation to marine litter, an EcoQO on **"Plastic particles in seabird stomachs"** had to be developed. Initiated in the Netherlands, an EcoQO has been developed monitoring the amount of plastic in stomachs of beached Northern Fulmars, *Fulmarus glacialis*. Fulmars are purely oceanic foragers, ingest all sorts of litter from the sea surface, and do not regurgitate poorly degradable diet components, but slowly wear these down in the stomach. Accumulated plastic items in stomachs of beached Fulmars thus integrate litter levels encountered over a number of weeks in a particular marine area.

The ***Fulmar Plastic EcoQO*** has been described in an OSPAR background document and in the recent Quality Status Report (OSPAR 2008, 2010a, 2010b). OSPAR currently formulates its target for acceptable ecological quality in the North Sea as:

> *"There should be less than 10% of Northern Fulmars having 0.1 gram or more plastic in the stomach in samples of 50-100 beached fulmars from each of 5 different regions of the North Sea over a period of at least 5 years".*

Within the Netherlands, the Fulmar monitoring has been supported by governmental funding in relation to the EU Directive on Port Reception Facilities (Directive 2000/59/EC)(EC 2000). North Sea wide monitoring was initiated with support from the EU Interreg IIIB 2002-2004 project Save the North Sea with results published in van Franeker et al 2005) . The project was continued with support from NYK Group Europe Ltd with publication of international results up to 2006 in Van Franeker et al (2008). Although the group has managed to continue the collection of beached birds up to now, the analyses of the stomachs and reporting had to be put on hold until additional financing is found.

In 2008, it was proposed to OSPAR countries around the North Sea, to each contribute annually 10 k€ ex VAT to the Dutch government to be integrated into a single IMARES North Sea project comparable to the earlier EU and NYK products. However, only Norway responded to this request allowing an update of Norwegian data up to 2008, resulting in this report

The Fulmar Plastic EcoQO approach is probably becoming an indicator for 'Good Environmental Status (GES)' in the European Marine Strategy Framework Directive (MSFD) which hopefully stimulates integrated Fulmar monitoring (EC 2008, EC2010, Galgani et al 2010).

Project components

Within this project, it has been agreed to:

1. analyse available Fulmar stomachs collected by the Norwegian partner(*) over the years 2007 and 2008
2. to arrange transport to Netherlands of Fulmars collected by the Norwegian partner in 2009, and to store these frozen for later analyses
3. to write a short report on the results in EcoQO format, that allows comparison of Norwegian data (up to 2008) to those collected in the Netherlands. *It should be noted that it is normally not feasible to run a separate project and reporting within the 10 KE budget, as the proposed contribution level assumed integrated contributions from many countries.*

(*) Lista area Beached Bird Survey: Coordinator: Olsen, K.O., Postveien 43, N-4563 BORHAUG, NORWAY

Products

1. Sixteen Norwegian Fulmars collected over 2007 and 2008 were dissected. Fifteen of the birds contained stomachs. Stomach contents were analysed and data added to the database. Results are discussed below.
2. A total of 21 Fulmars collected in Norway over year 2009 was transported to the Netherlands in late September 2010, and are now held in freezer storage awaiting new funding. *The pickup of material was arranged in combination with travel to and from the OSPAR Ministerial Conference in Bergen, where a demonstration was given to the ministers of a Fulmar dissection and where a large exhibition display was shown. For related media attention incl. video fragment please see the IMARES webpage on plastic wastes in the marine environment. http://www.imares.wur.nl/UK/research/dossiers/plastic . In relation to this meeting some preliminary data were also provided to the Norwegian ministry of the Environment*
3. Report of results in EcoQO format is given below in this report.

Results of Fulmar-Plastic-EcoQO Research in Norway up to 2008.

The metric for discussion of amounts of, and trends in plastics in stomachs of fulmars for the plastic particle EcoQO focuses on the mass of plastics in stomachs, in which the

- **Annual data** are provided but should be dealt with carefully as short-term variations, especially for smaller sample sizes, could be misleading. Therefore, data are better considered not by separate years, but by:
  - **'current situation**' which is described by the average for the last 5-year period (now: 2004-2008),
  - **'long-term trend**' refers to the full dataset (now 1979-2008, not applicable yet to data outside of the Netherlands)
  - '**recent trend**' is defined as trend over the past 10 years (now 1999-2008), and
- Trends are **tested** for statistical significance by linear regressions of ln-transformed plastic data of individual birds against year.
- **EcoQO performance** is expressed as the percentage of birds that has more than 0.1 gram of plastic in the stomach.

Over the 2003-2008 period a total of 62 Fulmar stomachs from the Lista area in southern Norway have been examined.

Annual data & current situation

Table 1 and Figure 1 provide basic data on incidence, number and mass of plastics in Fulmars from Lista Norway on an annual basis. Considerable annual differences are visible in the proportion of birds exceeding the critical EcoQO level, ranging from 29 to 100% of birds examined. It has to be emphasized that the Fulmar EcoQO methodology recommends considering data over periods of 5 years, to avoid confusion from annual fluctuations. This is especially true when considering separate locations in isolation, with maybe small annual sample sizes as in the case of Lista.

Current situation

Averaged over the recent 5-year period (2004-2008), 42% of 55 Norwegian Fulmars examined, exceed the critical limit of 0.1 gram of plastic in the stomach. Incidence of plastics over this period was high, with 98% of birds having plastic in the stomach, on average 46 pieces and plastic mass of 0.33 g per bird *(bottom line Table 1)***.**

In the Netherlands, Fulmars beached over the 2004-2008 period (van Franeker 2010) exceeded the 0.1g level in a considerably higher 62% of cases. However, in the Netherlands, incidence (93%) number of items (27.4), and mass (0.3 gram) were somewhat lower than the Norwegian figures for this period. The discrepancy between the EcoQO comparison and direct comparison of averages confirms that in smaller datasets a few exceptional birds can make important differences. The EcoQO metric is based on proportions of birds above and below a critical level and thereby is not influenced by a few extreme outliers. So, in spite of higher average number and mass of plastic in Norwegian Fulmars, the lower EcoQO metric indicates that the Norwegian birds are somewhat cleaner than those from the Netherlands.

Averaged over the earlier 2003-2007 5-year period in the Lista area (also 55 birds), about 51% exceeded the critical level. The difference should not be seen as a meaningful decrease, due to the small samples for 2003 and 2008 that are involved.

Table 1 ***Annual details for plastic abundance in Fulmars from Lista, southern Norway.*** *For separate and combined plastic categories, incidence (%) represents the proportion of birds with one or more items of that litter present, number (n) abundance by average number of items per bird, and mass (g) abundance by average mass per bird in grams. The column on the far right indicates level of performance in relation to the OSPAR EcoQO, viz. the percentage of birds having more than the critical level of 0.1 gram of plastic in the stomach. The bottom line of the table shows the 'current' situation as the average over the past 5 years. Note sample sizes (n) to be low for particular years implying low reliability of the annual averages for such years, not to be used as separate figures. Also note erratic variability in age proportions of birds in samples, where age is known to influence amount of litter in the stomach.*

			INDUSTRIAL PLASTICS			USER PLASTICS			ALL PLASTICS (industrial + user)			EcoQO
YEAR	*n*	% adult	%	n	g	%	n	g	%	n	g	> 0.1 g
2003	***7***	**33%**	**86%**	**2.4**	**0.07**	**100%**	**32.3**	**0.34**	**100%**	**34.7**	**0.41**	**100%**
2004	***26***	**85%**	**62%**	**7.1**	**0.10**	**96%**	**57.9**	**0.26**	**96%**	**65.0**	**0.37**	**42%**
2005	***10***	**75%**	**20%**	**0.4**	**0.01**	**100%**	**30.3**	**0.34**	**100%**	**30.7**	**0.35**	**50%**
2006	***4***	**75%**	**50%**	**1.0**	**0.02**	**100%**	**13.8**	**0.13**	**100%**	**14.8**	**0.15**	**50%**
2007	***8***	**67%**	**38%**	**2.4**	**0.07**	**100%**	**15.1**	**0.25**	**100%**	**17.5**	**0.31**	**38%**
2008	***7***	**33%**	**57%**	**4.9**	**0.09**	**100%**	**41.0**	**0.19**	**100%**	**45.9**	**0.27**	**29%**
2009	*(21 birds collected and in storage)*											
2004-08	***55***	**74%**	**49%**	**4.5**	**0.07**	**98%**	**41.3**	**0.26**	**98%**	**45.7**	**0.33**	**42%**

* Five-year data w ere averaged over all individual birds in the five year period (so not from annual averages)

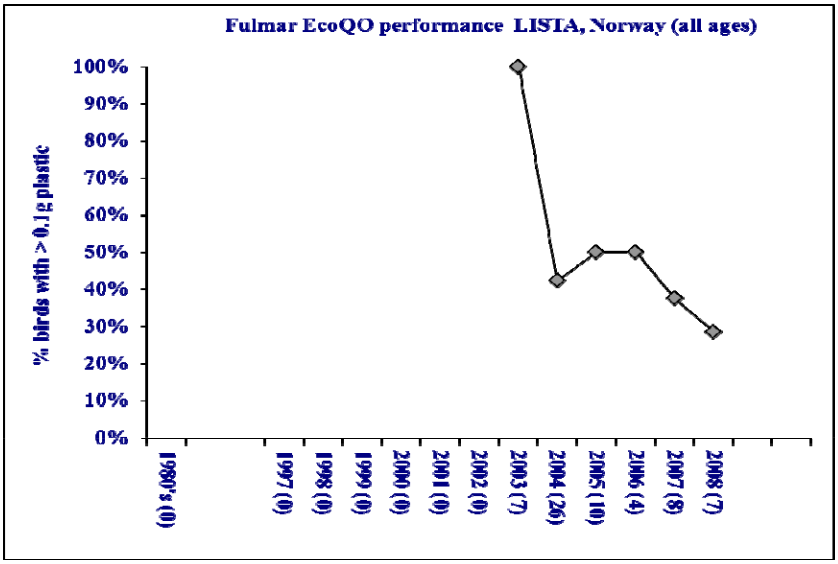

Figure 1. Annual variations in EcoQO performance of Fulmars from Lista, Norway. NB watch small sample sizes shown in x-axis with further details in Table 1)

Another way to reduce the potentially confounding effect of incidental 'outliers' on data interpretation, is to use so called 'normalised' data, for example by using geometric means, derived from ln-transformed data. The geometric mean mass of plastic in Norwegian Fulmars over the 2004-2008 period is 0.082g (Table 2). The geometric mean mass of plastics in 290 Fulmars examined over this period in the Netherlands is 0.096g.

Thus, EcoQO performance and geometric mean mass of plastics in the stomachs indicate that the Norwegian fulmar stomachs are somewhat 'cleaner' than those from the Netherlands, reflecting a lower level of debris in the Norwegian area.

Details of composition of plastic litter, as well as some information on non-plastic rubbish encountered in the stomachs is shown in Table 2 for the current (=5 year) situation.

Table 2 Summary of sample characteristics and stomach contents of Fulmars collected for Norwegian marine litter monitoring over the 5-year period 2004-2008. 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). Currently, only age is known to affect the amount of litter in stomachs. 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 of items per bird stomach, average mass 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-transformed values as used in trend-analyses.

	5 YEAR PERIOD	nr of birds	adult	male	LL colour	death oil	avg condition
	2004-2008	**55**	**74%**	**56%**	**94%**	**13%**	**1.7**
		incidence	**average number of items**	**average mass of litter (g/bird) ± standard deviation**		**max. mass recorded**	**geometric mean mass (g/bird)**
1	**ALL PLASTICS**	**98%**	**45.7**	**0.328**	**± 0.540**	**1.9**	**0.0819**
1.1	**INDUSTRIAL PLASTIC**	**49%**	**4.5**	**0.072**	**± 0.139**	**0.6**	**0.0074**
1.2	**USER PLASTIC**	**98%**	**41.3**	**0.256**	**± 0.445**	**1.7**	**0.0586**
1.2.1	sheets	56%	4.6	0.010	± 0.029	0.2	0.0021
1.2.2	threads	49%	1.3	0.003	± 0.005	0.0	0.0013
1.2.3	foamed	60%	7.2	0.028	± 0.098	0.7	0.0031
1.2.4	fragments	93%	27.7	0.206	± 0.400	1.6	0.0358
1.2.5	other plastic	18%	0.6	0.010	± 0.040	0.2	0.0007
2	**OTHER RUBBISH**	**13%**	**0.8**	**0.073**	**± 0.461**	**3.4**	**0.0007**
2.1	paper	4%	0.0	0.055	± 0.380	2.8	0.0003
2.2	kitchenwaste (food)	11%	0.7	0.017	± 0.082	0.6	0.0005
2.3	rubbish various	5%	0.1	0.001	± 0.005	0.0	0.0001
2.4	fishhook	0%	0.0	0.000	± 0.000	0.0	0.0000

Trend

Annual data for mass of plastics and EcoQO performance in Table 1 suggest a drop in pollution levels over the years. The amount of data available is rather limited for statistical testing (in Dutch material tests for recent trends done over a 10 year period). The standard test to evaluate change is by linear regression of all individual ln-transformed values for mass against the year of collection. When the currently available 62 birds from Lista are tested this way, the sign of the results is negative, **suggesting a downward trend, but nowhere near a significant level** (t-value -1.04, p=0.305). Longer time series will be needed to clarify trends.

Material available for follow up

The 2009 sample from Lista has 21birds, a relatively good number for this location, and will assist further conclusions. If funds can be found before the end of 2010, analysis of these birds will be possible in the period up to March 2011. The result could then be incorporated in the 2009 update report that is being prepared for the Dutch government. The publication of that report is scheduled to be published in May 2011.

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Relevant websites

- http://www.imares.wur.nl/UK/research/dossiers/plastic/
- www.zeevogelgroep.nl *click on downloads – Fulmar-Litter-Study*

Appendix II United Kingdom EcoQO Report (update 2009, final)

United Kingdom EcoQO Report (update 2009, final)

1 DEFRA Project Code **ME5209**
2 Project Title
Using Northern Fulmars as an Ecological Monitor of Marine Litter in Line with Indicators set for the MSFD Descriptor 10
3 DEFRA Project Manager: **Carly Brooks**
4 Contractor **IMARES, PO Box 167, 1790 AD Den Burg, Texel, The Netherlands**
5 contractors Project manager **Jan A. van Franeker**
6 Project start date **12-Jul-2010** **end date** **31-Nov-2012**

7 Scientific Objectives
The objective of this project is to provide monitoring data on marine litter using the methodology of the Fulmar-Plastic-EcoQO developed by OSPAR as one of the Ecological Quality Objectives for the North Sea. This method is now also being developed for assessments of 'Good Environmental Status (GES)' in the Marine Strategy Framework Directive.

Approaches and research plan
Within this project, Fulmars collected from the 3 existing North Sea North Sea locations (Shetlands, Orkneys, East England) in years 2008, 2009 and 2010 will be analysed and data added to the existing series of data which starts 2002/2003. The 2008+2009 update will be delivered ultimately in May 2011, the 2010 update in May 2012, parallel to and incorporated in the Dutch monitoring report series. In addition to the report, detailed UK data for separated locations will be made available to DEFRA in the format desired. Research approach and methodology is described in:

OSPAR 2008. Background Document for the EcoQO on plastic particles in stomachs of seabirds. OSPAR Commission, Biodiversity Series. ISBN 978-1-905859-94-8 Publication Number: 355/2008. OSPAR, London, 13pp

which contains references to further methodological details.
Possibly starting 2010, beached fulmars from other locations around the UK may be delivered to IMARES for analysis. The expansion in number of UK locations for collection of beached birds is not a task for IMARES in this contract, but may be set up by DEFRA via its contacts with e.g. the British Trust for Ornithology. If the number of Fulmars from 2010 (from existing plus new locations) substantially exceeds the annual average of about 50 birds, excess analyses will be only possible after adaptation of the contract.

8 Summary of progress
Project background and methods summary
At the request of the North Sea ministers (2002), OSPAR, with the support of ICES, has implemented a system of Ecological Quality Objectives (EcoQOs) for the North Sea. In relation to marine litter, an EcoQO on "Plastic particles in seabird stomachs" had to be developed. An existing Dutch approach, that monitors the amount of plastic in stomachs of beached Northern Fulmars (Fulmarus glacialis) was adopted by OSPAR. Fulmars are purely oceanic foragers, ingest all sorts of litter from the sea surface, and do not regurgitate poorly degradable diet components, but slowly wear these down in the stomach. Accumulated plastic items in stomachs of beached Fulmars thus integrate litter levels encountered over a number of weeks in a particular marine area. The Fulmar Plastic EcoQO has been described in an OSPAR background document and in the recent Quality Status Report (OSPAR 2008, 2010a, 2010b). OSPAR currently formulates its target for acceptable ecological quality in the North Sea as:

“There should be less than 10% of Northern Fulmars having 0.1 gram or more plastic in the stomach in samples of 50-100 beached fulmars from each of 5 different regions of the North Sea over a period of at least 5 years”.

Within the Netherlands, the Fulmar monitoring has been supported by governmental funding in relation to the EU Directive on Port Reception Facilities (Directive 2000/59/EC)(EC 2000). North Sea wide monitoring was initiated with support from the EU Interreg IIIB 2002-2004 project Save the North Sea with results published in van Franeker et al 2005) . The project was continued with support from NYK Group Europe Ltd with publication of international results up to 2006 in Van Franeker et al (2008). Although the group has managed to continue the collection of beached birds up to now, the analyses of the stomachs and reporting had to be put on hold, and now depends on contributions from participating OSPAR countries. This method is now also being developed for assessments of ‘Good Environmental Status (GES)’ in the Marine Strategy Framework Directive (MSFD) which hopefully stimulates integrated Fulmar monitoring (EC 2008, EC2010, Galgani et al 2010).

The metric for discussion of plastic abundance in stomachs of fulmars and trends focuses on the mass of the plastics, in which the following terminology and conventions apply:

- **ANNUAL DATA** are provided but should be dealt with carefully as short-term variations, especially for smaller sample sizes, can be misleading. Data are better considered by the:
- **'CURRENT LEVEL'** which is described by the average for birds over the last 5-year period (now: 2005-2009),
- **TRENDS** are either considered as ***RECENT*** that is over the past 10 years (now 1999-2008)' or over the ***LONG-TERM*** which refers to the full dataset (for the Netherlands 1979-2009, not applicable yet to data outside of the Netherlands)
- **TESTS** for statistical significance of trends use linear regression analyses of ln-transformed plastic data of individual birds against year.
- **EcoQO PERFORMANCE**, or compliance is expressed as the percentage of birds that has more than 0.1 gram of plastic in the stomach.

Results

Fulmars for the EcoQO research in the UK have been collected in Shetland, Orkney and eastern England since 2002 and 2003. Over the 2002-2009 period a total of 272 fulmar stomachs from the UK were analysed (Shetland 112, Orkney 62, East England 98). Annual details, and summary lines for the last 5-year period and the full dataset are provided in the location appendices tables A1, B1 and C1. Details for various types of plastics and other litter in the fulmar stomachs in the current (5-year) period are specified in the appendix tables A2, B2 and C2. EcoQO performance over 'running' 5-year periods is shown in the Appendix Figures A1, B1 and C1.

The current 5-year situation for the three UK locations is summarized in Table 1 and compared to the situation in the Netherlands (van Franeker et al 2011). Remarkably, where in the initial years of the Save the North Sea study (van Franeker et al. 2005), fulmars from the Scottish islands were noticeably cleaner than those from the Netherlands (Fig.1), this difference now seems largely disappeared. Comparisons are best made by geometric mean mass of plastics or EcoQO %, and both show little difference between Scotland and the Netherlands in the most recent 5 years. Preliminary tests for trends in the UK data suggest increases in litter abundance for all three locations, but only weakly significant for the Shetland Islands. Sample sizes are relatively small and only start in 2002 or 2003 and show high variability (see standard errors in Table 1). A test on the large dataset for fulmars on the

Dutch coast suggests stable or slightly decreasing levels over the past 10 years, but also not significant. The opposite trends between UK and Dutch locations explain the increased similarity between the locations in the recent 5-year period, in which the English fulmars even exceed the Dutch pollution level.
***CONCLUSION:* at the UK monitoring sites, as anywhere in the North Sea, the current litter levels shown by fulmar stomach contents are much higher than the OSPAR EcoQO target and likely the GES target. For tests of trends, the overall period and samples sizes are still rather limited: analyses suggest increases in litter, but weakly significant only in Shetland.**

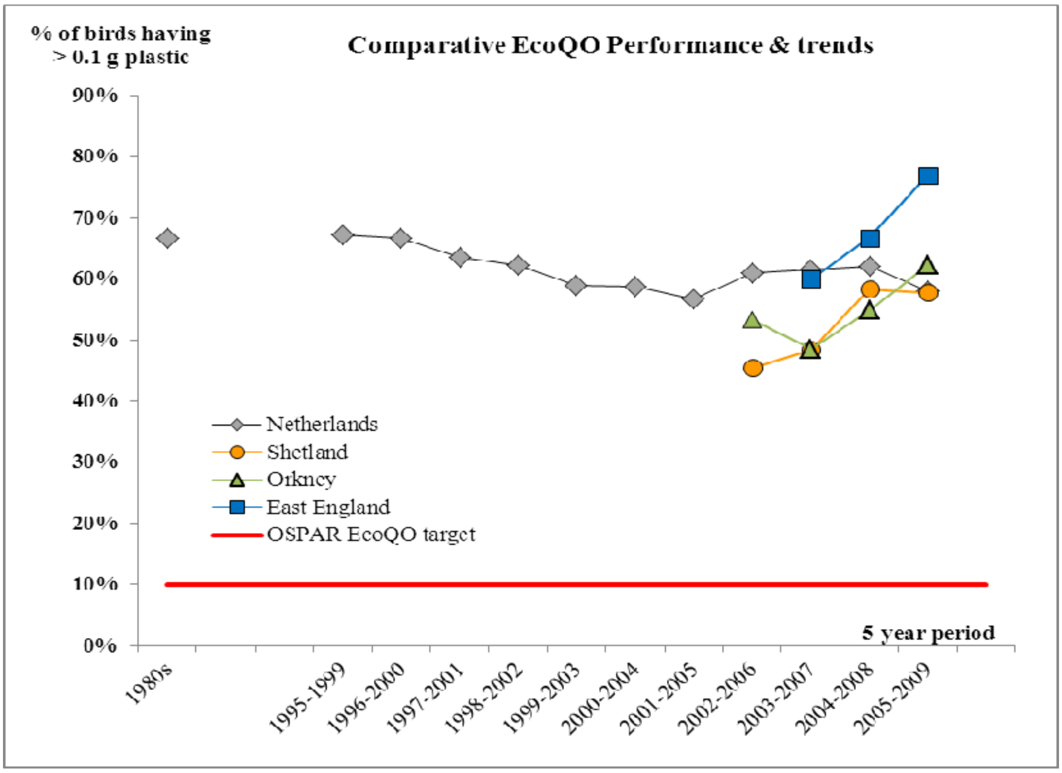

Figure 1 Changes in EcoQO performance of fulmars in different UK locations and the Netherlands *(see appendices for details).*

Table 1 Current level (5-year average 2005-2009) and trends in plastic abundance in stomachs of fulmars from locations in the United Kingdom and in the Netherlands *(see appendices for details).*

Current levels												*Trend*
2005-2009			plastic incidence	avg nr of plastic particles per bird		average mass of plastic per bird		max	geom mean	EcoQO %		*2000-2009*
	n	*adult*	%	n	±se	g	±se	g	g	> 0.1 g		
Shetland	*71*	*70%*	93%	22.1	± 4.0	0.30	± 0.07	4.4	0.093	**58%**		↑ ***p=0.036***
Orkney	*37*	*34%*	86%	26.7	± 7.2	0.48	± 0.16	4.8	0.097	**62%**		↑ ***n.s.***
E. England	*52*	*57%*	98%	46.5	± 6.4	0.36	± 0.06	2.6	0.162	**77%**		↑ ***n.s.***
Netherlands	*227*	*51%*	95%	27.3	± 2.5	0.29	± 0.03	2.4	0.102	**58%**		↓ ***n.s.***

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9. Amendments to the project None

10. Progress in relation to targets

No changes are needed as remaining milestones look realistic

Milestone number	description	Target date	Met in full?	Met on time?
1	Preliminary report on 2008 and 2009 results for UK, in combination with 2009 update Dutch long term monitoring	30 Nov 2010	yes	yes
2	Final EcoQO Report update to 2009 for participating North Sea countries, including UK	31 May 2011		
3	Preliminary report on 2010 results for UK, in combination with 2010 update Dutch long term monitoring	20 Nov 2011		
4	Final EcoQO Report update to 2010 for participating North Sea countries, including UK	31 May 2012		

11. Publications and other outputs

Activities/outputs directly related to this project (MSFD, OSPAR, UK research):

2010

Galgani, F., Fleet, D., **Van Franeker, J.,** Katsanevakis, S., Maes, T., Mouat, J. , Oosterbaan, L., Poitou, I., Hanke, G., Thompson, R., Amato, E., Birkun, A., & Janssen, C. 2010. Marine Strategy Framework Directive - Task Group 10 Report Marine litter. ***JRC Scientific and Technical Reports, Publications Office of the European Union - EUR 24340*** *EN OPOCE LB-NA-24340-EN-N, 57pp.*

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Van Franeker, J.A. 2010. Fulmar Litter EcoQO Monitoring in the Netherlands 1979-2008 in relation to EU Directive 2000/59/EC on Port Reception Facilities. ***IMARES Report nr C027/10.*** IMARES, Wageninge-UR, Texel. 40pp.

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UNEP 2011. UNEP Year Book 2011: Emerging issues in our global environment. United Nations Environment Programme, Nairobi, 79pp. (IMARES Research shown in chapter titled 'Plastic Debris in the Ocean' on pages 20-

Regular updates to items project websites

- http://www.imares.wur.nl/UK/research/dossiers/plastic/
- www.zeevogelgroep.nl click on downloads – Fulmar-Litter-Study

12. Future work

This project allows more detail in the Fulmar Litter EcoQO research than was hitherto possible, and will lead to improved scientific quality in output and new planning

13. Declaration

I declare that the information I have given is correct to the best of my knowledge and belief

J.A. van Franeker, IMARES Scientist, 31 May 2011

Next pages Appendices to:
United Kingdom EcoQO Report (update 2009, final)

Appendix A *(United Kingdom EcoQO Report: update 2009, final)*: **Shetland details**

Table A1 **Annual details for plastic abundance in Fulmars from Shetland, UK.** For separate and combined plastic categories, incidence (%) represents the proportion of birds with one or more items of that litter present, number (n) abundance by average number of items per bird, and mass (g) abundance by average mass per bird in grams. The column on the far right indicates level of performance in relation to the OSPAR EcoQO, viz. the percentage of birds having more than the critical level of 0.1 gram of plastic in the stomach. The bottom lines of the table show the 'current' situation as the average over the past 5 years, and the data for the complete data series. Note sample sizes (n) to be low for particular years implying low reliability of the annual averages for such years, not to be used as separate figures. Also note erratic variability in age proportions of birds in samples, where age is known to influence amount of litter in the stomach.

Shetland, UK			INDUSTRIAL PLASTICS			USER PLASTICS			ALL PLASTICS (industrial + user)			EcoQO
YEAR	*n*	% adult	%	n	g	%	n	g	%	n	g	> 0.1 g
2002	***11***	**82%**	**45%**	**1.8**	**0.05**	**73%**	**13.7**	**0.30**	**73%**	**15.5**	**0.35**	**45%**
2003	***13***	**69%**	**23%**	**0.5**	**0.01**	**85%**	**8.5**	**0.05**	**85%**	**9.1**	**0.06**	**23%**
2004	***17***	**82%**	**41%**	**1.7**	**0.04**	**100%**	**17.0**	**0.13**	**100%**	**18.7**	**0.17**	**53%**
2005	***5***	**60%**	**40%**	**0.4**	**0.00**	**100%**	**7.4**	**0.24**	**100%**	**7.8**	**0.25**	**60%**
2006	***9***	**67%**	**22%**	**0.3**	**0.01**	**100%**	**18.7**	**0.11**	**100%**	**19.0**	**0.12**	**56%**
2007	***18***	**61%**	**33%**	**1.5**	**0.03**	**89%**	**14.2**	**0.21**	**89%**	**15.7**	**0.24**	**56%**
2008	***23***	**68%**	**61%**	**1.7**	**0.04**	**96%**	**34.9**	**0.46**	**96%**	**36.6**	**0.50**	**65%**
2009	***16***	**87%**	**38%**	**1.0**	**0.02**	**88%**	**13.6**	**0.19**	**88%**	**14.6**	**0.22**	**50%**
2005-2009	***71***	**70%**	**42%**	**1.2**	**0.03**	**93%**	**20.9**	**0.28**	**93%**	**22.1**	**0.30**	**58%**
all to 2009	***112***	**72%**	**40%**	**1.3**	**0.03**	**91%**	**18.1**	**0.23**	**91%**	**19.4**	**0.26**	**52%**

* multi-year data averaged over all individual birds in the period, so not derived from annual averages

Table A2 **Summary of sample characteristics and stomach contents of Fulmars collected for Shetland marine litter monitoring over the 5-year period 2005-2009.** 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). Currently, only age is known to affect the amount of litter in stomachs. 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 of items per bird stomach, average mass 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-transformed values as used in trend-analyses.

	SHETLAND	nr of birds	adult	male	LL colour	death oil	avg condition	
	2005-2009	**71**	**70%**	**44%**	**93%**	**14%**	**2.8**	

		incidence	average number of items (n/bird) ± se		average mass of litter (g/bird) ± se		max. mass recorded	geometric mean mass (g/bird)
1.0	**ALL PLASTICS**	**93%**	**22.1**	**± 4.008**	**0.304**	**± 0.070**	**4.4**	**0.0926**
1.1	**INDUSTRIAL PLASTIC**	**42%**	**1.2**	**± 0.291**	**0.028**	**± 0.007**	**0.3**	**0.0038**
1.2	**USER PLASTIC**	**93%**	**20.9**	**± 3.931**	**0.277**	**± 0.069**	**4.4**	**0.0797**
1.2.1	sheets	31%	1.5	± 0.610	0.005	± 0.004	0.3	0.0007
1.2.2	threads	52%	1.5	± 0.461	0.015	± 0.007	0.4	0.0020
1.2.3	foamed	46%	5.0	± 1.627	0.024	± 0.011	0.7	0.0023
1.2.4	fragments	89%	11.9	± 2.320	0.220	± 0.058	3.7	0.0505
1.2.5	other plastic	13%	0.8	± 0.559	0.012	± 0.006	0.4	0.0007
2.0	**OTHER RUBBISH**	**7%**	**0.7**	**± 0.455**	**0.014**	**± 0.008**	**0.4**	**0.0003**
2.1	paper	0%	0.0	± 0.000	0.000	± 0.000	0.0	0.0000
2.2	kitchenwaste (food)	4%	0.6	± 0.416	0.010	± 0.007	0.4	0.0002
2.3	rubbish various	4%	0.1	± 0.059	0.003	± 0.003	0.2	0.0001
2.4	fishhook	0%	0.0	± 0.000	0.000	± 0.000	0.0	0.0000

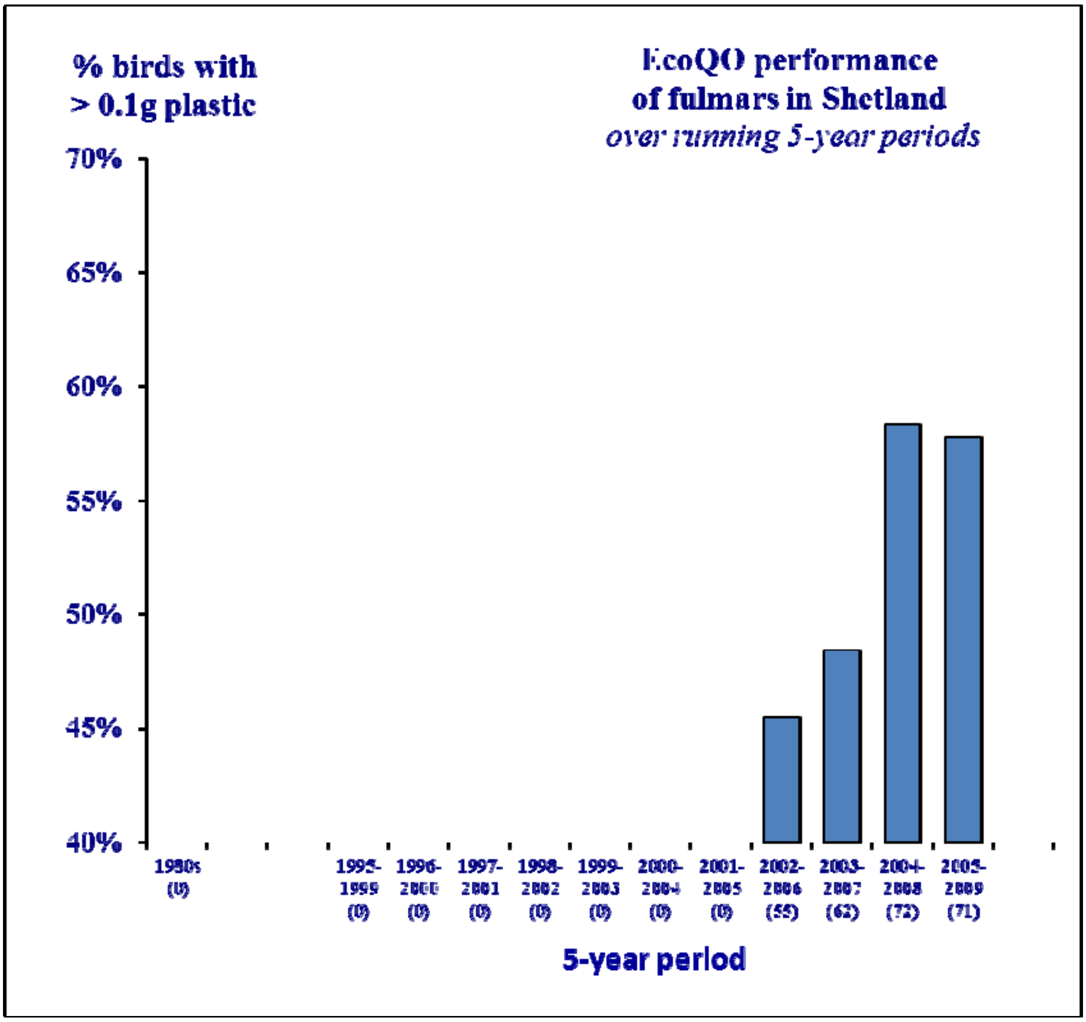

Figure A1 **Changes in EcoQO performance of Fulmars from the Shetland Islands up to 2009**. Running 'five-year-averages' for the percentage of beached fulmars having more than 0.1g of plastic in the stomach. Samples sizes are given in brackets below the x-axis labels. Note that y-axis scale is zoomed in on a restricted range of percentages well above the 10% OSPAR EcoQO target.

Table B1 **Annual details for plastic abundance in Fulmars from Orkney, UK.** (explanations see table A1)

Orkney, UK			INDUSTRIAL PLASTICS			USER PLASTICS			ALL PLASTICS (industrial + user)			EcoQO
YEAR	*n*	% adult	%	n	g	%	n	g	%	n	g	> 0.1 g
2002	***6***	**33%**	**67%**	**3.3**	**0.07**	**100%**	**28.0**	**0.25**	**100%**	**31.3**	**0.32**	**67%**
2003	***11***	**80%**	**73%**	**2.6**	**0.06**	**91%**	**21.9**	**0.22**	**91%**	**24.5**	**0.29**	**45%**
2004	***8***	**71%**	**25%**	**2.0**	**0.05**	**100%**	**27.4**	**0.19**	**100%**	**29.4**	**0.24**	**38%**
2005	***2***	**100%**	**0%**	**0.0**	**0.00**	**50%**	**9.5**	**0.14**	**50%**	**9.5**	**0.14**	**50%**
2006	***3***	**0%**	**67%**	**1.3**	**0.03**	**100%**	**78.0**	**0.40**	**100%**	**79.3**	**0.42**	**100%**
2007	***9***	**37%**	**33%**	**0.7**	**0.01**	**78%**	**10.7**	**0.25**	**78%**	**11.3**	**0.26**	**44%**
2008	***9***	**22%**	**56%**	**1.7**	**0.04**	**89%**	**9.7**	**0.70**	**89%**	**11.3**	**0.74**	**67%**
2009	***14***	**31%**	**57%**	**1.1**	**0.03**	**93%**	**36.6**	**0.49**	**93%**	**37.7**	**0.51**	**64%**
2005-2009	***37***	**34%**	**49%**	**1.1**	**0.02**	**86%**	**25.6**	**0.46**	**86%**	**26.7**	**0.48**	**62%**
all to 2009	***62***	**47%**	**52%**	**1.7**	**0.04**	**90%**	**25.4**	**0.36**	**90%**	**27.1**	**0.40**	**56%**

* multi-year data averaged over all individual birds in the period, so not derived from annual averages

Table B2 **Summary of sample characteristics and stomach contents of Fulmars collected for Orkney marine litter monitoring over the 5-year period 2005-2009.** (explanations see table B1)

	ORKNEY	nr of birds	adult	male	LL colour	death oil	avg condition	
	2005-2009	**37**	**34%**	**57%**	**97%**	**0%**	**1.8**	

		incidence	average number of items (n/bird) ± se		average mass of litter (g/bird) ± se		max. mass recorded	geometric mean mass (g/bird)
1.0	**ALL PLASTICS**	**86%**	**26.7**	**± 7.223**	**0.481**	**± 0.159**	**4.8**	**0.0973**
1.1	**INDUSTRIAL PLASTIC**	**49%**	**1.1**	**± 0.282**	**0.025**	**± 0.006**	**0.2**	**0.0052**
1.2	**USER PLASTIC**	**86%**	**25.6**	**± 7.119**	**0.456**	**± 0.158**	**4.8**	**0.0832**
1.2.1	sheets	38%	1.5	± 0.558	0.007	± 0.004	0.2	0.0011
1.2.2	threads	30%	1.4	± 0.651	0.009	± 0.006	0.2	0.0010
1.2.3	foamed	57%	4.6	± 1.549	0.031	± 0.019	0.7	0.0031
1.2.4	fragments	81%	17.8	± 5.172	0.265	± 0.090	3.1	0.0477
1.2.5	other plastic	14%	0.4	± 0.199	0.144	± 0.129	4.8	0.0011
2.0	**OTHER RUBBISH**	**14%**	**0.2**	**± 0.085**	**0.043**	**± 0.040**	**1.5**	**0.0006**
2.1	paper	0%	0.0	± 0.000	0.000	± 0.000	0.0	0.0000
2.2	kitchenwaste (food)	11%	0.1	± 0.069	0.003	± 0.002	0.0	0.0003
2.3	rubbish various	0%	0.0	± 0.000	0.000	± 0.000	0.0	0.0000
2.4	fishhook	3%	0.1	± 0.054	0.041	± 0.041	1.5	0.0002

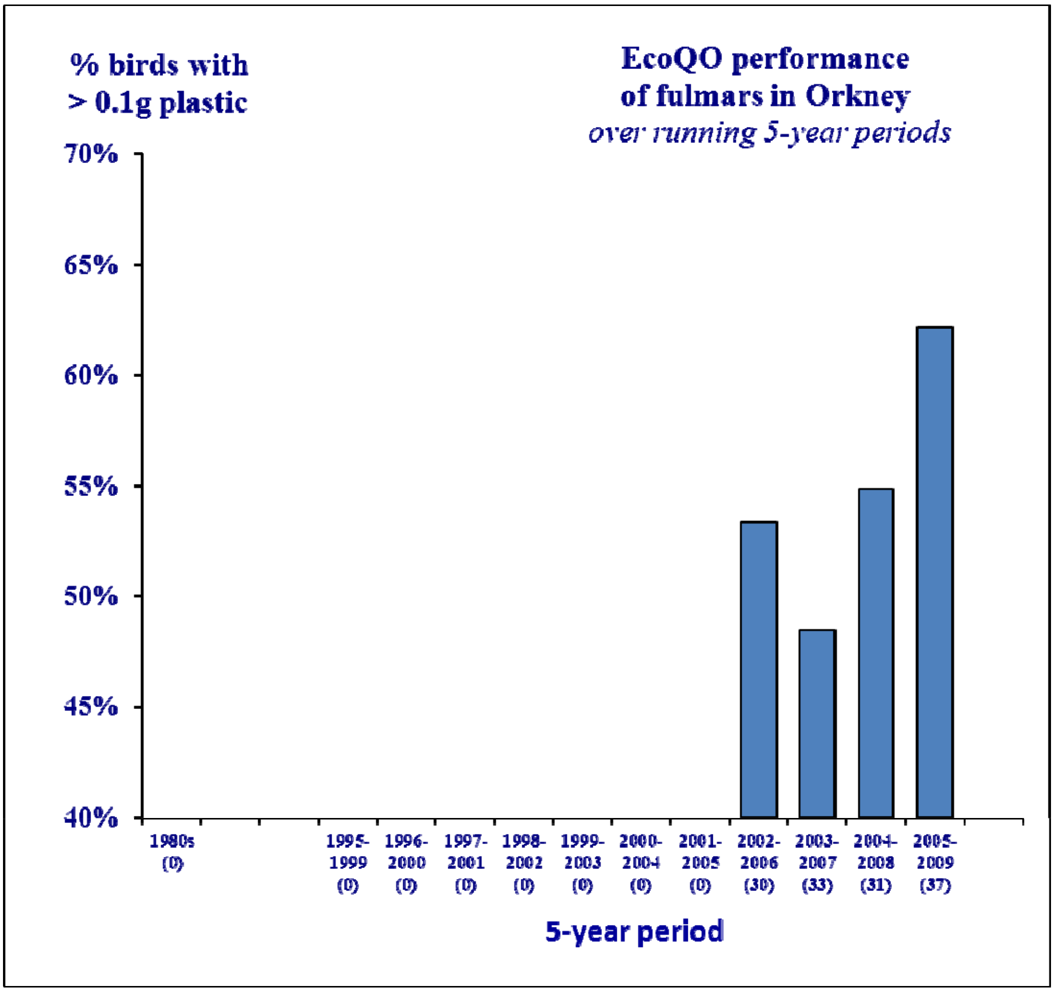

Figure B1 **Changes in EcoQO performance of Fulmars from the Orkney Islands up to 2009**. Running 'five-year-averages' for the percentage of beached fulmars having more than 0.1g of plastic in the stomach. Samples sizes are given in brackets below the x-axis labels. Note that y-axis scale is zoomed in on a restricted range of percentages well above the 10% OSPAR EcoQO target.

Appendix C *(United Kingdom EcoQO Report: update 2009, final)*: **East England details**

Table C1 **Annual details for plastic abundance in Fulmars from East England, UK.** (explanations see table A1)

East England, UK			INDUSTRIAL PLASTICS			USER PLASTICS			ALL PLASTICS (industrial + user)			EcoQO
YEAR	*n*	% adult	%	n	g	%	n	g	%	n	g	> 0.1 g
2003	***1***	**0%**	**100%**	**6.0**	**0.24**	**100%**	**10.0**	**0.11**	**100%**	**16.0**	**0.35**	**100%**
2004	***45***	**91%**	**49%**	**1.9**	**0.04**	**93%**	**26.3**	**0.16**	**93%**	**28.2**	**0.20**	**53%**
2005	***6***	**83%**	**67%**	**5.3**	**0.11**	**100%**	**23.5**	**0.22**	**100%**	**28.8**	**0.34**	**83%**
2006	***2***	**0%**	**100%**	**2.5**	**0.08**	**100%**	**37.0**	**0.28**	**100%**	**39.5**	**0.36**	**100%**
2007	***6***	**40%**	**67%**	**5.5**	**0.13**	**100%**	**88.3**	**0.19**	**100%**	**93.8**	**0.32**	**67%**
2008	***31***	**59%**	**77%**	**5.3**	**0.12**	**97%**	**40.9**	**0.21**	**97%**	**46.2**	**0.33**	**81%**
2009	***7***	**60%**	**57%**	**1.3**	**0.03**	**100%**	**22.9**	**0.49**	**100%**	**24.1**	**0.52**	**57%**
2005-2009	***52***	**57%**	**73%**	**4.7**	**0.10**	**98%**	**41.8**	**0.25**	**98%**	**46.5**	**0.36**	**77%**
all to 2009	***98***	**73%**	**62%**	**3.4**	**0.08**	**96%**	**34.4**	**0.21**	**96%**	**37.8**	**0.28**	**66%**

* multi-year data averaged over all individual birds in the period, so not derived from annual averages

Table C2 **Summary of sample characteristics and stomach contents of Fulmars collected from east England marine litter monitoring over the 5-year period 2005-2009.** (explanations see table B1)

	East England	nr of birds	adult	male	LL colour	death oil	avg condition	
	2005-2009	**52**	**57%**	**43%**	**98%**	**0%**	**1.3**	

		incidence	average number of items (n/bird)	± se	average mass of litter (g/bird)	± se	max. mass recorded	geometric mean mass (g/bird)
1.0	**ALL PLASTICS**	**98%**	**46.5**	**± 6.418**	**0.355**	**± 0.064**	**2.6**	**0.1622**
1.1	**INDUSTRIAL PLASTIC**	**73%**	**4.7**	**± 0.880**	**0.105**	**± 0.020**	**0.6**	**0.0264**
1.2	**USER PLASTIC**	**98%**	**41.8**	**± 5.994**	**0.250**	**± 0.056**	**2.6**	**0.1035**
1.2.1	sheets	81%	6.1	± 1.145	0.009	± 0.002	0.1	0.0040
1.2.2	threads	56%	3.1	± 0.923	0.009	± 0.003	0.1	0.0020
1.2.3	foamed	85%	11.0	± 2.734	0.014	± 0.003	0.1	0.0057
1.2.4	fragments	94%	20.6	± 2.686	0.205	± 0.055	2.6	0.0692
1.2.5	other plastic	21%	1.2	± 0.622	0.013	± 0.008	0.4	0.0010
2.0	**OTHER RUBBISH**	**38%**	**1.0**	**± 0.315**	**0.662**	**± 0.432**	**20.0**	**0.0027**
2.1	paper	6%	0.1	± 0.033	0.000	± 0.000	0.0	0.0000
2.2	kitchenwaste (food)	38%	0.9	± 0.269	0.582	± 0.426	20.0	0.0022
2.3	rubbish various	2%	0.0	± 0.038	0.000	± 0.000	0.0	0.0001
2.4	fishhook	2%	0.0	± 0.038	0.080	± 0.080	4.2	0.0002

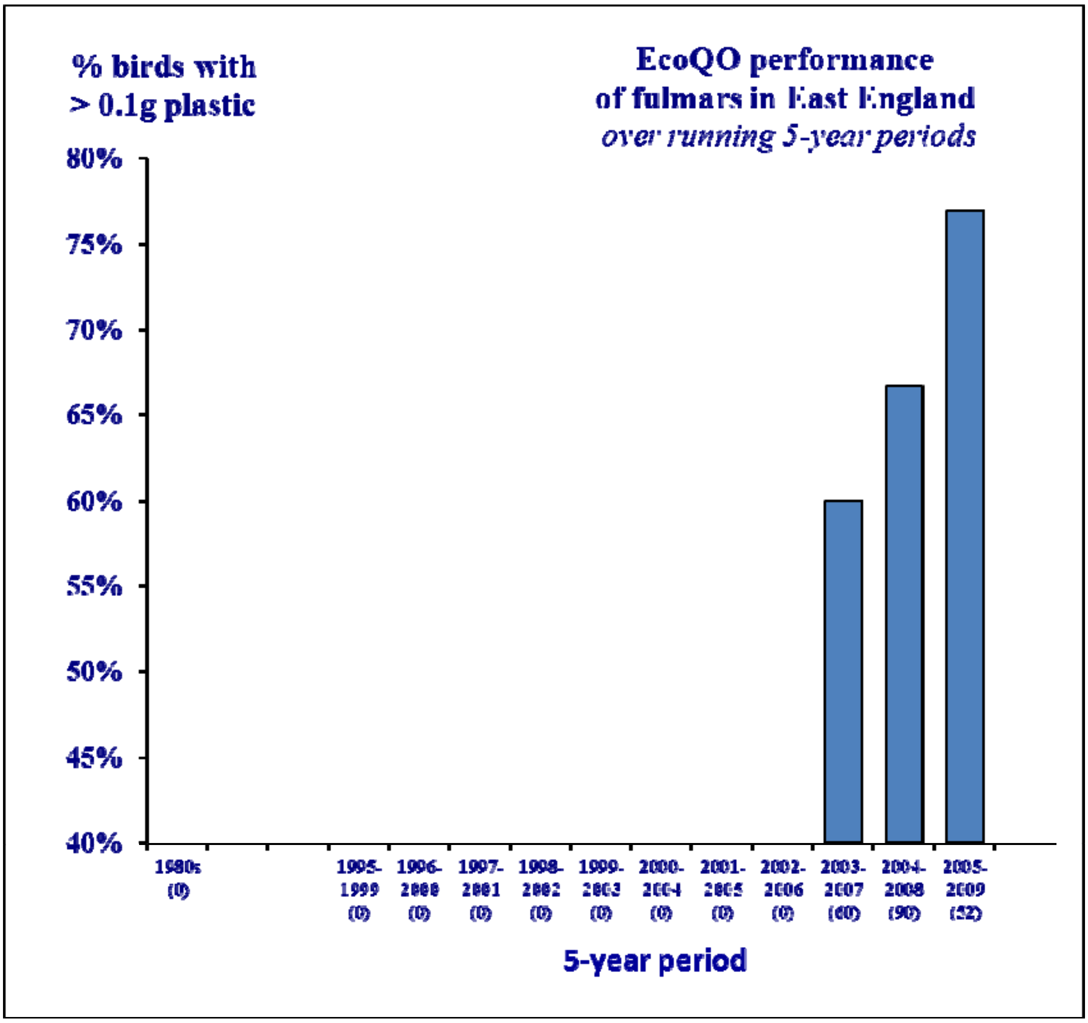

Figure C1 **Changes in EcoQO performance of Fulmars from the east England up to 2009**. Running 'five-year-averages' for the percentage of beached fulmars having more than 0.1g of plastic in the stomach. Samples sizes are given in brackets below the x-axis labels. Note that y-axis scale is zoomed in on a restricted range of percentages well above the 10% OSPAR EcoQO target.