capable of keeping their feeding apparatus functional for a substantial length of time. The major cause of death, hence appears to be the animals' incapability of assimilating enough nutrients to satisfy metabolic maintenance costs.

Discussion

Both *C. intestinalis* and *A. scabra* are very sensitive to the quantity of inorganic material suspended in the water column, *C. intestinalis* seemingly being the more susceptible. Reduced growth rates of *A. scabra*, at the lower of the concentrations tested, however, may be detrimental to the overall viability of the population. The rapid growth of both species under control conditions illustrates the capabilities of certain ascidians as opportunistic fouling organisms.

Increased inorganic particulate suspension concentrations have been shown to cause reduced growth rates and mortality in other filter feeding organisms (Loosanoff, 1962; Turner, 1971; Chang & Chin, 1978; Incze *et al.*, 1980 for bivalve molluscs; Johnson, 1972 for the prosobranch mollusc *Crepidula fornicata*), and the general quality of the suspended particulate load has been shown to be of considerable importance in the growth of bivalve molluscs (Bayne & Widdows, 1978; Vahl, 1980). Clearly phleobranchiate ascidians show no exception to these trends, and indeed are especially sensitive owing to their lack of particle selection and pseudofaecal production.

In the natural environment, ascidians tend to be excluded from areas with high concentrations of inorganic particulate material, and flourish in clearer waters. Acute, often non-natural, increases in turbidity do occur, and Monniot (1945, cited in Millar, 1971) has recorded the destruction of an abundant population of *Ascidia* sp. following disturbance of the sea bed.

Bayne, B. L. & Widdows, J. (1978). The physiological ecology of two populations of *Mytilus edulis* L. *Oecologia* **37**, 137–142.
Chang, S. D. & Chin, P. (1978). Effects of suspended silt and clay on the mortality of some species of bivalves. *Bull. Korean Fish. Soc.* **11**, 227–231.
Chester, R. & Stoner, J. (1972). Concentration of suspended particulate matter in surface seawater. *Nature, Lond.* **240**, 552–553.
Incze, L. S., Lutz, R. A. & Watling, L. (1980). Relationships between effects of environmental temperature and seston on growth and mortality of *Mytilus edulis* in a temperate northern estuary. *Mar. Biol.* **57**, 147–156.
Johnson, J. K. (1972). Effect of turbidity on the rate of filtration and growth of the slipper limpet, *Crepidula fornicata* Lamark, 1799. *Veliger* **14**, 315–320.
Loosanoff, V. L. (1962). Effects of turbidity on some larval and adult bivalves. *Proc. Gulf Caribb. Fish. Inst.* **14**, 80–94.
Mackin, J. G. (1962). Suspended silt levels accompanying dredging activities. *Publs Inst. mar. Sci. Univ. Tex.* **7**, 262–314.
Millar, R. H. (1952). The annual growth and reproductive cycle in four ascidians. *J. mar. biol. Ass. U.K.* **31**, 41–61.
Millar, R. H. (1971). The biology of ascidians. *Adv. mar. Biol.* **9**, 1–100.
Moore, P. G. (1977). Inorganic particulate suspensions in the sea and their effects on marine animals. *Oceanogr. mar. Biol. ann. Rev.* **15**, 225–363.
Padan, J. W. (1971). In *Marine Mining and the Environment* (D. W. Hood, ed), pp. 553–561. Wiley-Interscience, New York.
Robbins, I. J. (1983). The effects of body size, temperature and suspension density on the filtration and ingstion of inorganic particulate suspensions by ascidians. *J. exp. mar. Biol. Ecol.* **70**, 65–78.
Robbins, I. J. (1985). Food passage and defaecation in *Ciona intestinalis* L.; the effects of suspension quantity and quality. *J. exp. mar. Biol. Ecol.* (in press).
Turner, B. R. (1971). The effects of an increased Ca^{++} concentration on the Pismo clam, *Tivela stultorum* (Mawe). *Tech. Publ. Moss Ldg mar. Lab.* **71**, 12–20.
Vahl, O. (1980). Seasonal variations in seston and in the growth rate of the Iceland scallop, *Chlamys islandica* (O. F. Müller) from Balsfjord, 70°N. *J. exp. mar. Biol. Ecol.* **48**, 195–204.

Marine Pollution Bulletin, Vol. 16, No. 9, pp. 367–369, 1985
Printed in Great Britain
0025-326X/85 $3.00+0.00

Plastic Ingestion in the North Atlantic Fulmar

J. A. van FRANEKER
Institute of Taxonomic Zoology, University of Amsterdam, Postbus 20125, 1000 HC Amsterdam, Netherlands

Fulmars found dead on the Dutch coast, and fulmars collected in arctic colonies have considerable quantities of plastic in their stomachs. The average number of plastic items ingested is almost twelve in Dutch fulmars, and four to five in arctic fulmars. User-plastics and industrial plastics are about equally abundant. Ingestion of user-plastics suggests a stronger impact of toxic chemicals from plastics than generally assumed.

Studies of fulmars, *Fulmarus glacialis*, washed ashore in the Netherlands and of fulmars in arctic colonies were started in 1980. Initially, stomach contents were examined superficially, but frequent observations of plastics soon led to a more accurate approach: in 1982 a first sample showed an average of about five plastic particles in stomachs of fulmars beached in the Netherlands (van Franeker, 1983). This paper discusses the results of further study on the presence of plastics in stomachs of fulmars found in the Netherlands and of fulmars collected in arctic colonies. Earlier publications on plastic ingestion by fulmars are by Bourne (1976), Baltz & Morejohn (1976), Day (1980) and Furness (1985a).

Types of plastic

By their origin, plastics occurring at sea may be separated into two major types. The most conspicuous one is *user-plastic* and consists of all types of plastics regularly used by man, like plastic bags, cups, bottles, packaging materials, and ropes and nets. Major sources of these objects at sea are commercial shipping and fisheries (Dixon & Dixon, 1981), but rivers and direct dumping undoubtedly add land-generated litter. A large part of the plastic occurs as fragments after breaking up of the original items.

The second and less conspicuous type is *industrial plastic:* small granules, generally with a diameter of less than 4 mm. Most granules are shaped like cylinders or disks, but spherical and rectangular shapes occur as well. These small plastic particles are the industrial bulk material in which plastics are produced and transported before being transformed to the 'user-plastics' by remelting and the use of additives. The granules are lost both during manufacturing (Shiber, 1979) and transport (Gregory, 1978).

Upon inspection of plastics in stomachs of fulmars, items were separated into user-plastics and industrial plastics. User-plastics were further categorized into: sheets; foamed plastics; threads; (fragments of) moulded plastics; and 'others' (e.g. cigarette-filters and elastics). Only the number of objects of each type of plastic was noted, and no attempt was made to determine weights or volumes.

Results

From December 1982 to January 1984, 79 fulmars found dead on the Dutch coast were dissected: 65 corpses still contained stomachs, the others had probably been devoured by gulls, skuas, or fulmars. The mean number of plastic objects in these stomachs was 11.9 per bird, with a maximum of 96 fragments in a single individual. In total, 92% of the stomachs contained plastics (Table 1). Slightly over one half of the plastics found were of the industrial type; the remainder consisted of different types of user-plastics, in which fragments of moulded plastics were most frequent. Stomach contents of 22 fulmars collected at Bear Island (74° 24′ N–19° 00′ E) in plastics were most frequent.

Stomach contents of 22 fulmars collected at Bear Island (74° 24′ N–19° 00′ E) in 1980, and 29 fulmars collected at Jan Kayen (71° 00′ N–09° 00′ W) in 1983, were analysed in the same way as those of fulmars found dead in the Netherlands (Table 1). In spite of the large distance of these arctic colonies from industrial areas or major

TABLE 1

Mean number of plastic objects in stomachs of Fulmars from the southern North Sea (Holland), Bear Island and Jan Mayen.

	Holland $n=65$	Bear Island $n=22$	Jan Mayen $n=29$
Industrial	6.2 (38; 72%)	1.1 (11; 36%)	2.3 (14; 62%)
Sheets	0.8 (9; 31%)	0.4 (3; 27%)	0.1 (2; 7%)
Foamed	1.2 (20; 28%)	0	+ (1; 3%)
Thread	0.4 (4; 29%)	1.3 (12; 32%)	0.2 (2; 21%)
Moulded	2.7 (40; 52%)	1.5 (7; 59%)	2.0 (10; 62%)
Others	0.5 (13; 25%)	0.1 (1; 14%)	0
Total	11.9 (96; 92%)	4.5 (23; 82%)	4.7 (26; 79%)

Plastics are distinguished in an industrial type and several types of user-plastics (see text). Shown in brackets are the maximum number of objects found in one stomach, and the percentage of birds of the sample having plastic in the stomach.

TABLE 2

Frequency distributions of numbers of plastic objects in stomachs of Fulmars from the southern North Sea (Holland), Bear Island, and Jan Mayen.

Number of plastic objects	Holland $n=65$	Bear Island $n=22$	Jan Mayen $n=29$
0	5 (8%)	4 (18%)	6 (21%)
1	6	6	5
2	4	0	4
3	5	3	0
4	9	0	2
5	3 (58%)	1 (73%)	2 (69%)
6	2	4	2
7	1	0	4
8	3	2	0
9	4	0	1
10	1	0	0
11–20	10 (15%)	1 (5%)	2 (7%)
21–30	7 (11%)	1 (5%)	1 (3%)
31–40	3 (5%)	0	0
41–50	0	0	0
>50	2 (3%)	0	0

Shown are the actual number of birds (and the percentage of the sample) having a certain number of plastic objects in the stomach.

shipping routes, about 80% of the fulmars at both islands contained plastics. The mean number of plastic objects was four to five per stomach. At Jan Mayen the relative proportions of industrial and user-plastics were similar to those of North Sea fulmars found in Holland. In Bear Island fulmars, less industrial plastic occurs, but user-plastics make up for the difference.

Since an average may be distorted by a few exceptionally large figures, the actual number of plastic framents found in the fulmars of all three localities is summarized in Table 2. Sizes of samples are too small to result in clear-cut frequency distributions, but it is evident that plastic ingestion is extremely common in fulmars all over the North Atlantic. The higher mean in Dutch fulmars is not caused by a few exceptional birds: about 34% of these North Sea birds had more than ten plastic objects in the stomach whereas this figure was only 10% in arctic fulmars.

In the above, only plastic ingestion is discussed, but judging from stomach contents, fulmars will swallow almost anything available near the ocean surface. Small pieces of driftwood, seaweed, and plant-seeds may be considered as natural objects. Pieces of paper, silver-foil, tea-bags, a large onion, bulbs of garlic, fishing-hooks, and other objects, are examples of human litter taken by fulmars. Occasionally even small tarballs are ingested, a phenomenon also reported from the great shearwater, *Puffinus gravis,* and sooty shearwater, *P. griseus* (Brown *et al.,* 1981).

Discussion

Day (1980) observed a mean number of 2.8 plastic particles in 38 fulmars collected near Alaska, and explained the higher average of 11.3 particles in three fulmars from California (Baltz & Morejohn, 1976) by the stronger pollution in that area. Probably the high figure for Dutch fulmars in this study as compared to those of Bear Island and Jan Mayen may be explained in a similar way.

Most fulmars found in Holland have suffered starvation, and might have taken a larger proportion of easily available, but unsuitable 'food'. However, recent data by Furness (1985a) show that such behaviour probably does not occur: in a sample of 13 fulmars collected at Foula, Shetland, plastic ingestion averaged 10.6 fragments per bird, which is very similar to the plastic ingestion by North Sea fulmars found in the Netherlands. Comparison of these recent data with the figures given by Bourne (1976) of one to two plastic items per bird suggest a sharp increase in plastic pollution and its effects in the North Sea in recent years.

In Fulmars from Bear Island and Jan Mayen, no analysis of the relationship between body weight and plastic ingestion was made because of strong weight variation due to sex, locality and breeding status. Several other studies have shown negative correlations between the amount of plastic in the stomach and the condition/weight of the bird (Day, 1980; Connors & Smith, 1982; Furness, 1985a, b). Correlations are weak however, and firm proof of cause and effect can be obtained only by an experimental approach.

Adverse effects of the ingestion of plastic are usually linked to mechanisms reducing the assimilation of food (Day, 1980). Relatively little attention has been given to the presence of toxic chemicals in plastics. Most studies inadvertently focused on industrial plastics. The industrial granules almost solely consist of plastic polymers, which are thought to be biologically inactive. However, large quantities of additives (colourants, softeners, antioxidants, etc.) are used when converting the granules to user-plastics. Many of the additives are known to be toxic and can be assimilated from plastics (Aldershoff, 1982). The considerable consumption of user-plastics by fulmars shows that intoxication by chemicals from plastics may be more important than hitherto assumed. The global character of the problem is emphasized by plastic ingestion in fulmars in remote arctic areas like Bear Island and Jan Mayen, although these birds may have ingested plastic in winter at some distance from the colonies.

Clearly there is a strong need for experiments to provide accurate data on effects, but immediate opposition to further plastic dumping in the oceans seems justified. A major step towards improvement of the present situation would be the implementation of Annex V in MARPOL by the International Maritime Organization. Annex V of MARPOL concerns waste dumping from ships, and totally prohibits the dumping of (user-)plastics. Loss of industrial plastic granules could be greatly reduced by relatively simple adjustments to processing and transport systems.

The Institute of Taxonomic Zoology provided facilities for my studies of fulmars. Members of the Dutch Oil-victim Research (NSO) collected dead fulmars from the Netherlands coast. Study of fulmars at Bear Island and Jan Mayen was supported by the Netherlands Organization for the Advancement of Pure Research (ZWO). Dr. J. Wattel and Dr. R. W. Furness kindly commented on earlier drafts of this paper.

Aldershoff, W. G. (1982). Gezondheidsaspecten van PVC voor levensmiddelen. *Plastica* **35**, 58–60.

Baltz, D. M. & Morejohn, G. V. (1976). Evidence from seabirds of plastic pollution off Central California. *Western Birds* 7, 111–112.

Bourne, W. R. P. (1976). Seabirds and Pollution. In *Marine Pollution* (R. Johnstone, ed.), pp. 403–502. Academic Press, London.

Brown, R. G. B., Barker, S. P., Gaskin, D. E. & Sandeman, M. R. (1981). The foods of great and sooty shearwaters *Puffinus gravis* and *P. griseus* in Eastern Canadian waters. *Ibis* **123**, 19–30.

Connors, P. G. & Smith, K. G. (1982). Oceanic plastic particle pollution: suspected effect on fat deposition in red phalaropes. *Mar. Pollut. Bull.* **13**, 18–20.

Day, R. H. (1980). The occurrence and characteristics of plastic pollution in Alaska's marine birds. M.S. Thesis, Univ. Alaska, Fairbanks.

Dixon, T. R. & Dixon, T. J. (1981). Marine litter surveillance. *Mar. Pollut. Bull.* **12**, 289–295.

Franeker, J. A. van (1983). Plastics—Een bedreiging voor zeevogels. *Nieuwsbrief NSO* **4**, 41–61.

Furness, R. W. (1985a). Plastic particle pollution: accumulation by Procellariiform seabirds at Scottish colonies. *Mar. Pollut. Bull.* **16**, 103–106.

Furness, R. W. (1985b). Ingestion of plastic particles by seabirds at Gough Island, South Atlantic Ocean. *Environ. Pollut.* (in press).

Gregory, M. R. (1978). Accumulation and distribution of virgin plastic granules on New Zealand beaches. *N.Z. Jl mar. Freshw. Res.* **12**, 399–414.

Shiber, J. G. (1979). Plastic pellets on the coast of Lebanon. *Mar. Pollut. Bull.* **10**, 28.

BASELINE

Marine Pollution Bulletin, Vol. 16, No. 9, pp. 369–371, 1985
Printed in Great Britain

0025-326X/85 $3.00+0.00

Distribution of Iron and Manganese in the Blanca Bay, Argentina

Samples of sea surface microlayer, subsurface seawater and surface sediment from Blanca Bay were collected monthly from April 1982 to April 1983, to study the spatial distributions for dissolved and suspended fractions, and total amount of Fe and Mn for sea surface microlayer and subsurface seawater. In addition, surface sediment samples were analysed by two extraction methods.

The area under study and location of sampling stations are shown in Fig. 1. Blanca Bay, nearly 80 km long, with depths ranging from 15 to 20 m, is located in southeastern Buenos Aires Province, Argentina. Small streams discharge throughout its length, their contribution is nearly 5 $m^3 s^{-1}$. At low tide this Bay encompasses an area of 400 km^2. At high tide the total area is nearly 1300 km^2. This area receives a large quantity of raw sewage from nearly 300 000 inhabitants of Bahía Blanca town, industrial wastes without pretreatment and runoff water from almost 4200 km^2 of cultivated land. Blanca Bay behaves as an estuary in periods of heavy rainfall.

Sea surface microlayer samples were taken by the technique of Garrett (1965). A screen made of 20 mesh polypropylene and held in an all-plastic frame (75 × 75 cm) was lowered vertically into the water, the film