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Floating Marine Pollution in 'the Gully' on the Continental Slope, Nova Scotia, Canada

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Visual surveys of large debris items and neuston net tows of small particulate pollution (including tar) were conducted in the mouth of the submarine canyon known as the Gully—200 km east of mainland Nova Scotia, Canada. Censuses were also performed in surrounding areas. Densities of three types of pollution in the Gully were calculated and compared to those found in surrounding areas and to those reported in recent literature from other areas of the world. The Gully had higher average densities of small and large debris but a lower average density of tar compared to surrounding areas. Due to limitations in the sampling technique, statistical comparisons were not possible. The density of large debris was greater in the Gully than in all but one other study while the density of small debris was less than most other studies. Density of tar was comparable to that found in other areas.

The Gully is a dramatic submarine canyon (up to 2000 m depth), 200 km east of Nova Scotia, Canada (Fig. 1). The biological significance of the area is apparent in the wealth of species found there, including marine birds (e.g. *Puffinus gravis* and *Oceanodroma leucorhoa*); many whales (*Physeter macrocephalus, Balaenoptera physalus, B. acutorostrata, B. borealis, Megaptera novaeangliae* and *Globicephala melas*); dolphins (*Lagenorhynchus acutus, Delphinus delphis* and *Stenella coeruleoalba*); and grey seals (*Halichoerus grypus*) (Faucher & Whitehead, 1991). In addition, it is home to 200–300 endangered northern bottlenose whales (*Hyperoodon ampullatus*). Recent research (Faucher & Whitehead, 1991) suggests that these whales are non-migratory and seen primarily in an area (~12×8 km) at the mouth of the Gully which is, therefore, invaluable to this species. Unfortunately, along with many living things, the Gully contains a great deal of human pollution, including lost fishing gear, plastics and tar balls.

The biological significance of particulate pollution is not yet totally understood. Laist (1987) provides a good review of problems incurred as a result of entanglement and ingestion by many marine animals. Recently (Lucas, 1992), an assessment of beach litter was carried out on Sable Island, a restricted-access island 50 km from the Gully; a deposition rate of 219 debris items km^{-1} $month^{-1}$ was reported, most originating from activities of the fishing industry. The study reported entanglement of two seal and three seabird species and ingestion of plastics by leatherback turtles. Assessments of particulate pollution employing neuston net tows and visual surveys have been undertaken in many of the world's oceans (Tables 1 and 2). Our study uses these techniques to compare density of particulate pollution in the Gully to surrounding areas and to other oceans.

Methods

Data were collected during three trips to the Gully in the summer of 1990 (7 weeks in total) aboard the 10 m sailing vessel, *Elendil*, in conjunction with northern bottlenose whale research.

Large debris

Visual surveys were made by one observer standing by the mast (the highest part of the boat) watching a 50 m transect on one side of the ship from the bow to directly abeam (Day & Shaw, 1987). Change in position data were used to calculate transect length and hence surface area sampled for density calculations. We encountered poor visibility due to fog, mist and cloud cover during 15 of the 20 transects which could have biased density estimates downward.

Some surveys were conducted simultaneously with transects searching acoustically for whales (the primary emphasis of the research team) and were interrupted regularly to listen for whales or terminated when whales were sighted. It was assumed that the boat did not move considerably during listenings and viewing was resumed as soon as the boat was back on course.

Fourteen of 20 transects were in or near the prime whale area at the mouth of the Gully, with others at various nearby locations (see Figs 1 and 2(a)). One was conducted in Shortland Canyon—an area approximately 50 km from the Gully (Fig. 2) with similar depth and distance from the mainland but without the same wealth of species (pers. obs.). Whenever possible, debris was brought on board for detailed identification

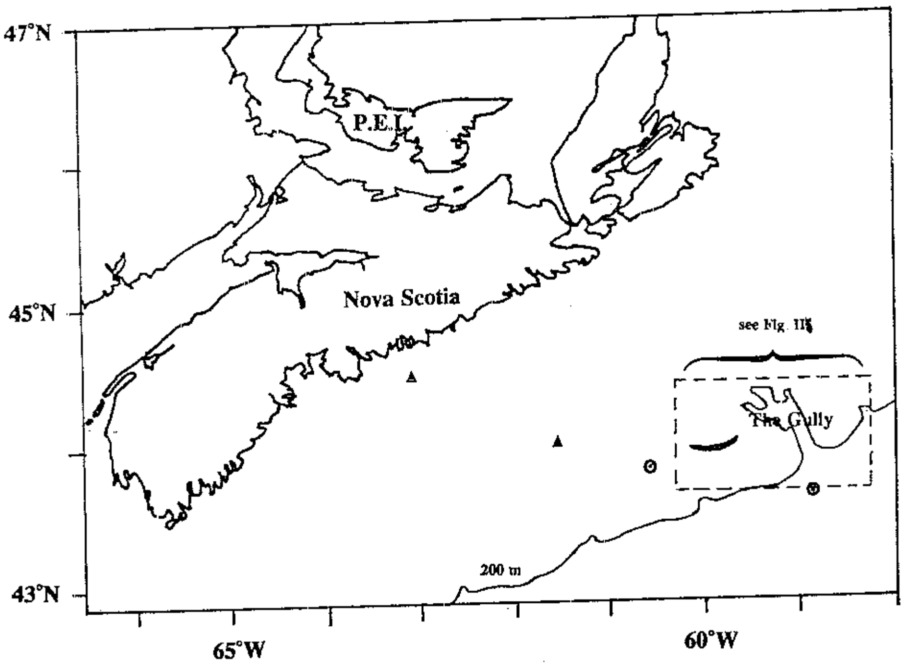

Fig. 1 Map showing location of 'the Gully' with respect to mainland Nova Scotia and locations of visual surveys (△) and neuston net tows (⊙) outside this area

TABLE 1

Review of findings from reports in the recent literature (large debris)

Location	Items km^{-2}	Reference
North Pacific	0–11.2	Dahlberg & Day, 1985
North Pacific	0.23–1.83	Day & Shaw, 1987
North Sea	0–3^{+}	Dixon & Dixon, 1983
Mediterranean	avg ≈ 2000	Morris, 1980b
Central North Pacific	avg. ≈ 4 24	Venrick *et al*, 1973

Small debris

A neuston net (Sameoto & Jaroszynski, 1969) was towed alongside the boat to collect small pieces of floating debris as used by others (Carpenter & Smith, 1972; Colton *et al.*, 1974; Day & Shaw, 1987; Morris, 1980a; Ryan, 1988; Van Dolah *et al.*, 1980; Wong *et al.*, 1974). The net (0.4×0.4 m opening; 308 μm mesh size) was towed out of the boat's wake (to avoid disturbance of the surface layer) for 20 min at approximately 5 5 km h^{-1} making the transect length 1.85 km (1 nautical mile); sampling a surface area of approximately 740 m^2 each transect. Seventeen of 25 transects were conducted in the mouth of the Gully with two others in Shortland Canyon (see Figs 1 and 2(b)).

Sorting samples at sea as in other studies (Day & Shaw, 1987; Colton *et al.*, 1974; Carpenter & Smith, 1972) proved difficult due to lack of lab facilities on board. Trial and error yielded the following method. Each sample was strained through a coffee filter which was then placed in a ziplock bag. Back in the lab, it was rinsed with fresh water and allowed to dry on the filter. Debris was then sorted from the sample by hand. Only samples collected by the above method (N17–N25) were used to calculate average densities. A dissecting microscope was used to confirm identity and determine size of debris items. Debris in samples N17–N25 were weighed on a Cahn electrobalance. Densities by weight and items m^{-2} were calculated for these samples. Tar was removed by hand at sea and placed in plastic bottles which were cut open in the lab and the tar scraped out using a scalpel. Tar was weighed on a Sartorius model 2842 balance; all samples were treated similarly and, hence, are comparable.

Results

Large debris

Debris was observed in all but one visual survey (Table 3). Densities ranged from 0 to 112 8 items km^{-2}. Only a single sample (near Sable Island) had no debris

TABLE 2

Review of findings from reports in the recent literature (small debris)

Location	Plastic (g km^{-2})	Tar (g km^{-2})	Reference
Sargasso Sea	0 6–1770 7	–	Carpenter & Smith, 1972
North West Atlantic	0–1403 5	–	Colton *et al.*, 1974
North Pacific	3 0–1210	0–21.5	Day & Shaw, 1987
South Atlantic	0–3600*	21 6–585 7	Morris, 1980a
South West Cape Province	0–10 920	–	Ryan, 1988
South Atlantic Bight	30–80	310–1950	Van Dolah *et al.*, 1980
Pacific	0–3500	0–14 000	Wong *et al*, 1974

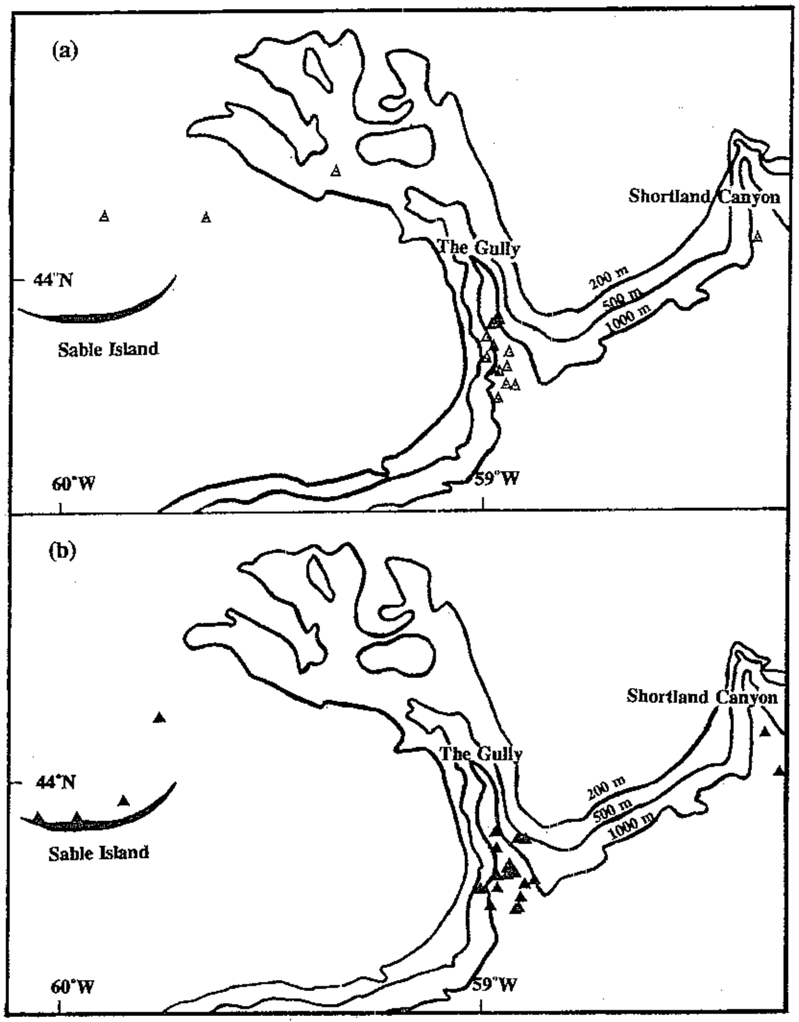

Fig. 2 Locations of visual surveys (a) and neuston net tows (b) in and around 'the Gully'

TABLE 3

Density of items seen in visual surveys for large debris

View No	Date	No of items	Length (km)	Items km^{-2}
Samples in the Gully region				
V1	06/19/1990	4	3 30	24 2
V2	06/22/1990	2	3 45	11 6
V3	06/22/1990	11	1 95	112.8
V4	06/22/1990	3	1 35	44 4
V5	06/23/1990	4	4 50	17 8
V6	06/26/1990	4	3 45	23 2
V10*	07/27/1990	3	4 80	12 5
V11	07/27/1990	11	3 75	58 7
V12	07/28/1990	2	3 45	11 6
V13	07/29/1990	5	2 40	41.7
V15*	08/05/1990	5	4 80	20 8
V16*	08/06/1990	3	6 60	9 1
V18*	08/09/1990	6	6.90	17.4
V19*	08/10/1990	13	7 05	36 9
Average				31.6 (sd=27.6)
Samples outside the Gully region				
V7	07/02/1990	2	3 60	11.1
V8†	07/26/1990	0	1 35	0 0
V9†	07/26/1990	3	5.25	11.4
V14*	08/04/1990	4	15.00	5 3
V17*‡	08/07/1990	11	6 60	33 3
V20	08/11/1990	2	7 80	5.1
Average				11.0 (sd=11 7)

*Concurrent with transects for whales
†Near Sable Island.

Average densities were 31 6 items km^{-2} (sd=27 6) in the Gully area and 11 0 items km^{-2} (sd=11.7) outside. Items included plastic grocery bags, nylon rope, potato chip bags, a styrofoam block and the lid from an ice cream container. All items with identifiable labels were traced to the Canadian maritime region.

Small debris

Plastics were found in 80% of tows and in all tows N17–N25 (Table 4). Density of debris by weight ranged from $2 1\times10^{-7}$ to $2 3\times10^{-5}$ g m^{-2}. Average densities were 1.20×10^{-5} g m^{-2} (sd=$8 10\times10^{-6}$) for the Gully region and 7.95×10^{-6} g m^{-2} (sd=7.41×10^{-6}) outside Items included bits of white styrofoam, textile fibres, fishing line, cellophane and hard plastic pieces (fragments of larger items). In addition, a few very small opaque spherules (diameter <1 mm) were found. These are similar to those reported in other surface waters (Carpenter & Smith, 1972; Colton *et al.*, 1974; Day & Shaw, 1987; Van Dolah *et al.*, 1980) and on beaches (Gregory, 1977, 1978, 1983; Lucas, 1992; Shiber, 1979, 1982) but much smaller.

Measurable amounts of tar were found in 72% of samples; an additional 8% contained trace amounts (Table 4) Weight densities ranged from 0 to $3 4\times10^{-4}$ g m^{-2} with one exception, a sample collected southwest

TABLE 4
Incidence of plastics and tar in neuston net tows.

Tow No.	Length (km)	Items m^{-2}	($g\ m^{-2}$)	Tar ($g\ m^{-2}$)
Samples in the mouth of the Gully				
N1	1 85	–	–	$9\ 0\times10^{-5}$
N2	1 61	–	–	$1\ 4\times10^{-6}$
N5	1 85	–	–	$4\ 1\times10^{-7}$
N6	1 72	–	–	$3\ 4\times10^{-4}$
N7	1 67	–	–	0
N8	1 67	–	–	0
N9	1 67	–	–	$1\ 0\times10^{-4}$
N11	1 91	–	–	$3\ 3\times10^{-6}$
N12	1 98	–	–	$1\ 7\times10^{-4}$
N13	1 98	–	–	$1\ 1\times10^{-6}$
N14	1.91	–	–	$2\ 1\times10^{-5}$
N15	1 85	–	–	0
N16	2.04	–	–	trace
N18	1 85	0.0203	$5\ 37\times10^{-6}$	3.6×10^{-6}
N19	1.98	0 0227	6.79×10^{-6}	1.1×10^{-6}
N20	1 72	0.0290	$1\ 27\times10^{-5}$	$2\ 3\times10^{-6}$
N23	1.72	0 2671	2.32×10^{-5}	0
Average		0 0848	1.20×10^{-5} (sd$=8\ 10\times10^{-6}$)	4.32×10^{-5} (sd$=9.06\times10^{-5}$)
Samples outside the mouth of the Gully				
N3*	2 04	–	–	0
N4*	1.72	–	–	$1\ 8\times10^{-4}$
N10*	1.85	–	–	$3\ 1\times10^{-6}$
N17*	1 98	0.0101	$4\ 54\times10^{-6}$	$1\ 3\times10^{-6}$
N21†	1 91	0 0878	$1\ 20\times10^{-5}$	trace
N22†	2 09	0 0382	$4\ 21\times10^{-6}$	$6\ 0\times10^{-7}$
N24	1 91	0.1088	$1\ 88\times10^{-5}$	1.4×10^{-6}
N25	1 85	0 0027	2.07×10^{-7}	$8\ 4\times10^{-2}$
Average		0 0495	$7\ 95\times10^{-6}$ (sd$=7\ 41\times10^{-6}$)	1.05×10^{-2} (sd$=2\ 97\times10^{-2}$)

*Taken near Sable Island
†Taken in Shortland Canyon

of Sable Island with a density of 8.4×10^{-2} g m^{-2}. Average tar densities were calculated as $4\ 32\times10^{-5}$ g m^{-2} (sd$=9\ 06\times10^{-5}$) in the Gully and $1\ 05\times10^{-2}$ g m^{-2} (sd$=2.97\times10^{-2}$) outside.

Discussion

The average density of large debris inside the mouth of the Gully was almost three times that seen outside this area but average density in both these regions was greater than that seen by others except Morris (1980b) who reported some 2000 items km^{-2} in the Mediterranean (Table 1). Average density of small debris by weight was 1.5 times greater in the mouth of the Gully than in surrounding areas. Both values were similar to other surveys (Table 2). We assumed a 100% sampling efficiency which may not be realistic, especially for two tows (N3 and N4) near Sable Island where the net became clogged with amphipods, reducing its efficiency and likely biasing estimates in these samples downward. Average weight density of tar was greater outside the Gully than inside. These values fell in the range of those found by others, with lower concentrations reported by Day & Shaw (1987) in the North Pacific and higher concentrations seen by Wong *et al.* (1974) in the Pacific (Table 2).

Limited sampling was done in Shortland Canyon, but

those found in the Gully. Sampling near Sable Island revealed densities lower than those seen in the Gully for both debris items but reduced net efficiency may have biased estimates of small debris near Sable Island downward. Both the visual survey (V20) and net tow (N25) on Sable Island Bank showed distributions of debris items more like those near Sable Island than those in the Gully Tar found here was the greatest of any sample.

The surface circulation of the area is proposed as a southward movement along the length of the Nova Scotian coast which then circles back offshore toward Sable Island and beyond creating a large cyclonic eddy centred at Sable Island (Smith *et al.*, 1978) Higher densities of debris in this area would be expected if debris were caught in this eddy Unfortunately, the small sample sizes and non-randomness of our sampling technique did not allow for statistical comparisons and, hence, our study provides only circumstantial evidence for greater densities of pollution in the Gully than surrounding areas

Reports have attributed a great deal of marine debris to the shipping industry (Pruter, 1987; Vauk & Schrey, 1987) but identifiable items found by us likely came from the local fishing industry or other small craft in the area. Possible harmful effects of this pollution to inhabitants of this biologically important area are not yet known and hence, it should be monitored for such impacts and protected

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