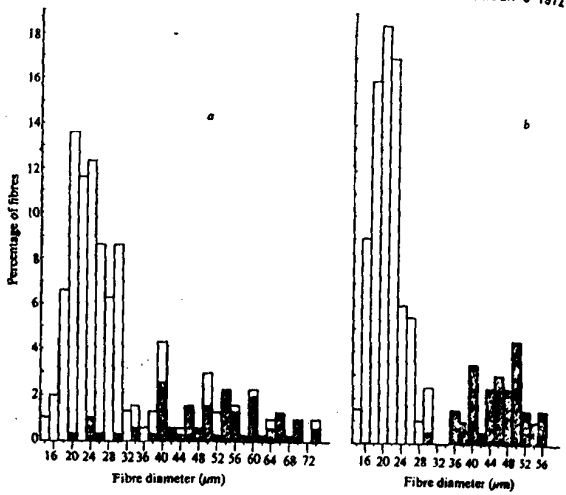


Fig. 1 Fibre diameter distributions of the two raw wool samples investigated. *a*, Straight-tipped; *b*, curly-tipped. Shaded parts indicate medullated fibre.

support for the constancy of diameter in fine fibres noted previously[4,5]. The mode in Bronze Age wool[3] ranged from 14 to 18 μm but since that time the mode of fine fibres has been about 20 μm.

The Pazirik and Hallstatt samples in fact comprised skin with the wool attached; within the skin the fibres had brush ends indicating a natural moult and the likely collection of the wool by plucking. Only one brush end was observed in the present samples suggesting that the wool had not been plucked; it would be extremely difficult to pluck a sheep unless brush ends had formed, but there were an appreciable number of the roots of pulled fibres, the remainder appearing like worn cut ends. Shears are thought to have been invented about 1000 BC[6], so it may be that this Egyptian wool had been cut off with a knife, the root ends belonging to fibres that had been dragged out by the knife instead of being cut. A knife was used in this way in north-west Britain recently during the decline of plucking and before the introduction of shears.

Table 1 Wool Measurements

		Staple length	Fibre diameter (μm) Range	Mean	Mode	% Medullated fibres	% Pigmented fibres
Yarn		—	18–66 74*	33.2	22	16	0
Straight tip	(a)	7 cm	18–70	33.9	20 and 24	33	2
	(b)	7 cm	14–46 50, 70, 74*	26.1	20	15	0
Curly tip	(a)	6 cm	14–54	26.0	22	21	0
	(b)	6 cm	14–56	27.0	20	26	0
		Overall range	14–74				
			Means	29.2	21.2	22	0.4
Other samples for comparison[3]							
Old Kingdom (ca. 2500 BC)		(2)	12–110	34.6	20	21	1
Pazirik (400 BC)		12	12–42 62–82*	28.2	22 and 70	14	0
Hallstatt (500 BC)		(3)	20–80 96, 100*	35.5	22	22	0

* Diameters of individual fibres occurring outside the main range are listed separately.

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Effects of Polychlorinated Biphenyl on Marine Phytoplankton Communities

We report here the first *in situ* bioassay of short term effects of polychlorinated biphenyl compounds (PCBs) on natural marine phytoplankton communities. (Synthesis and utilization of these industrial organochlorines have been discussed before[1–3].) PCB residues have been identified in water, biota and sediment samples throughout the marine environment[3–9]. Near Escambia Bay, Florida, industrial outfall water and sediment in the immediate outfall vicinity contained PCB residues as high as 275 p.p.b. (1 billion = 10^9) and 486 p.p.m. respectively. Live oysters approximately 10 miles downriver of the outfall contained residues as high as 3 p.p.m.[10]. Seven of ten municipal wastewater outfalls sampled along the California coastline were confirmed to carry PCB compounds[11].

Information about the physiological and ecological effects of PCBs in natural aquatic communities is limited.

We have investigated the effect *in situ* of a range in PCB concentrations to phytosynthetic radiocarbon uptake in natural communities of phytoplankton. Experiments were conducted in St George Sound in the northeastern Gulf of Mexico near Franklin County, Florida, during August–November 1970 and February–April 1971. Phytoplankton communities of St George Sound were quite heterogeneous, showing considerable variability even at a single station with less than 1 h between samplings. East–west tidal currents through the sound continually renewed water sampled and were felt to be the principal source of this sampling variability. Among the phytoplankton, diatoms were the most predominant group and were most frequently represented by the following genera[12]: *Cerataulina*, *Chaetoceros*, *Biddulphia*, *Eupodiscus*, *Leptocylindrica*, *Melosira*, *Nitzschia*, *Rhizosolenia*, and *Thallasionema*. Dinoflagellates were generally present as a few individuals of *Peridinium* and *Ceratium* were observed in most samples. Coccolithophores and silicoflagellates have been reported in the northeastern Gulf of Mexico samples but were not noted in this study[12]. The PCB compounds studied included 2,4'-dichlorobiphenyl, 'Aroclor 1242' and 'Aroclor 1254'. The two types of 'Aroclor' are isomeric mixtures of pure chlorinated biphenyl and differ by their respective degrees of chlorination: 42% and 54% 2,4'-dichlorobiphenyl is a pure PCB compound with 31.8% chlorine by weight and constitutes part of 'Aroclor 1232'. PCB effects were compared with *p,p'*-DDT, the major chemical constituent of commercially applied DDT formulations.

For each experiment a single 10-l. water sample was taken at 0.5 m to avoid sampling the surface film, shaken to homogenize plankton distribution and siphoned into duplicate or triplicate 240 ml. bottles. After the addition of seawater to the sample bottles, concentrations of organochlorine in ethanol solvent were added using 10 microlitre capacity syringes. The indicated organochlorine concentrations represent the initial concentrations and do not reflect any partitioning of organochlorine between plankton, suspended solids, bottle walls and water. Concentrations of ethanol less than 100 p.p.m. were not found to inhibit radiocarbon uptake; the maximum concentration of ethanol employed was 50 p.p.m.

In each experiment twenty-four to thirty bottles were filled and fastened in triads across a rectangular frame. The assembled frame was suspended from the surface by supporting buoys at approximately 1.5 m. After the 24 h organochlorine incubation period 5 μCi of $NaH^{14}CO_3$ was added to the bottles. The frames were reassembled and resuspended *in situ* for 4 h. To terminate the experiments, 1 ml. of buffered formalin was added and the samples were filtered through 47 (0.45 μm) membrane filters. After drying the filters over silica gel pads for 4–7 days, the radioactivity was determined by proportional counting technique. The results are reported as percentage uptake of radiocarbon by phytoplankton exposed to various concentrations of PCB relative to control populations.

The effects of *p,p'*-DDT and 2,4'-dichlorobiphenyl are compared in Fig. 1*a*. The toxicity of these compounds to phytoplankton is strikingly similar. DDT and 2,4'-dichlorobiphenyl inhibited phytoplankton radiocarbon uptake at 5 p.p.b. and 7 p.p.b. respectively. LC_{50} values for *p,p'*-DDT and 2,4'-dichlorobiphenyl were 35 p.p.b. and 30 p.p.b. respectively[10]. Wilcoxon two sample rank tests did not show differences between the toxicity of these compounds. 'Aroclor 1242' and 'Aroclor 1254' results are compared in Fig. 1*b*. Both isometric blends of polychlorinated biphenyl displayed greater toxicity to phytoplankton radiocarbon uptake than did either of the pure compounds, *p,p'*-DDT or 2,4'-dichlorobiphenyl. 'Aroclor 1242' and 'Aroclor 1254' were both toxic to phytoplankton populations at levels as low as 1–2 p.p.b. and showed LC_{50} values of 6.5 p.p.b. and 15 p.p.b., respectively. These concentrations are considerably below published 0.3–1.5 p.p.b. seawater solubility of 'Aroclor 1254'[13].

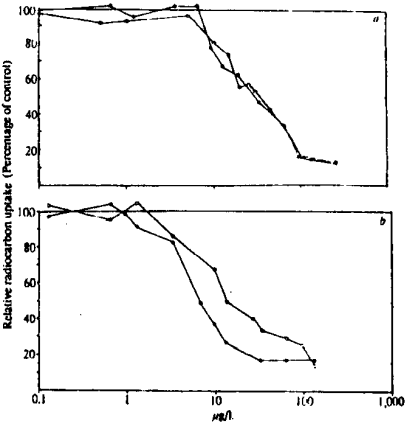


Fig. 1 Effect of organochlorines on *in situ* radiocarbon uptake by marine phytoplankton communities. *a*, *p,p'*-DDT (○) and 2,4'-dichlorobiphenyl (●); *b*, 'Aroclor 1242' (●) and 'Aroclor 1254' (○). See text for explanation.

'Aroclor 1254' is more toxic than an equivalent amount of DDT to the growth rates of two marine centric diatom species, *Skeletonema costatum* and *Thallastosira pseudonana*, in laboratory cultures[14]. Keil and others[15] demonstrated that the marine diatom *Cylindrotheca closterium* sorbed and concentrated 0.1 p.p.m. 'Aroclor 1242' up to 1,000 times with subsequent inhibited growth and diminished levels of chlorophyll and nucleic acids in laboratory cultures.

Inhibition of photosynthesis and growth of marine phytoplankton single-species cultures in the presence of organochlorine pesticides has been described before[16,17]. In natural phytoplankton communities all stages of growth are represented through various phytoplankton species. One might expect a natural community to exhibit PCB effects at lower concentrations than found in vigorously growing, pure cultures. While laboratory cultures are grown in controlled conditions ideally suited for that optimal growth rate, natural populations are subjected to various community stresses which may render plankton species more susceptible to organochlorine stress. Succession by one of two phytoplankton species in the presence of 'Aroclor' concentrations has been shown in laboratory conditions where levels as low as 1 p.p.b. were reported to alter competitive interactions between *T. pseudonana* and *Dunaliella tertiolecta* in culture[18]. The effects of PCBs reported in our studies suggest that the toxic effects of organochlorine are more acute *in situ* at a community level than for single species laboratory cultures. Any effort to establish water quality standards for PCB compounds should consider possible chronic effects on natural communities.

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Organochlorine Levels in Atlantic Seabirds

SYNTHETIC organochlorine derivatives have been found in a variety of seabirds from the eastern North Pacific[1] and even the Antarctic[2], and considerable amounts of polychlorinated biphenyls (PCBs) in particular have been found in birds from the Baltic[3], Dutch waters[4] and the livers of starving common guillemots, *Uria aalge*, washed ashore around the Irish Sea in the autumn of 1969[5]. But comparatively few estimates of the amounts present in normal seabirds from the open North Atlantic have yet been published. We are reporting elsewhere[6] the results of the investigation of over 100 birds from a representative range of species occurring between Scotland and the Arctic. In general they were all found to contain mainly PCBs and *pp'*-DDE, the former in greater concentration in every bird examined, in marked contrast to the North Pacific, where DDE levels are normally higher[1]. The ratio of PCB to DDE was usually between two and ten in all species with the exception of the kittiwake, *Rissa tridactyla*, where the ratio was always higher. It is difficult to measure DDE in the presence of relatively high amounts of PCBs but in some of the kittiwakes this ratio was at least 60. This suggests that kittiwakes have a food source relatively high in PCBs compared with the other species or, less likely, that they metabolize or excrete DDE more rapidly than the other species.

The total organochlorine content in muscle and liver was generally low in the auks and the few shearwaters examined, between 0.1–1.0 parts per million. The levels were higher in more pelagic species, in the kittiwake, fulmar, *Fulmarus glacialis*, and British storm-petrel, *Hydrobates pelagicus*, generally 1–10 p.p.m, and the highest levels rising above 10 p.p.m were found in large gulls and skuas feeding largely around trawlers in the winter and seabird breeding stations in the summer. In all the birds caught or shot the liver levels were normally of the same order as those in muscle, whilst in the birds found dead on beaches the liver levels were normally markedly raised compared to those in muscle. A common guillemot chick only contained a tenth the amount found in the adult accompanying it, so that it would appear that the organochlorine content is not inherited. The stomach oil of a fulmar which it feeds to its chick contained only 1.3 p.p.m. PCBs compared to 1.5 p.p.m. in the liver, 2.3 p.p.m. in the muscle and 42 p.p.m. in the fat, so that it appears that the parent does not pass on the levels found in the fat.

There was no substantial difference in the organochlorine content of birds obtained around the north of Scotland, the Faroes, and in the Barents Sea, and only the puffins *Fratercula arctica* began to show a diminution in the Davis Strait. Indeed, the highest levels were found in glaucous gulls, *Larus hyperboreus*, breeding above the seabird colonies on the cliffs of Bear Island. Normal birds, which appeared from regurgitated pellets to have been feeding largely on other seabirds' eggs, had an average content of 24 p.p.m. PCBs and 17 p.p.m. DDE in the liver, and one had 535 p.p.m. PCB and 67 p.p.m. DDE in the fat. Another bird showed a curious weakness and failure of coordination of the limbs, especially the legs, so that it fell sideways and threw itself about in a convulsion when it was approached so that it was easily caught by hand. On dissection, it was wasted and underweight but otherwise appeared normal. Its liver contained 311 p.p.m. PCBs and 67 p.p.m. DDE. Experimentally poisoned finches showed similar neurological signs and were found to have a mean liver PCB content of 345 p.p.m. at a dose rate sufficient to cause 50% mortality[7]. Thus this level of 311 p.p.m. PCBs in combination with DDE, which is also known to cause increased retention of PCBs mobilized from fat in starving robins *Erithacus rubecula*[8], is a possible cause of the symptoms. Whatever the cause of the bird's decline in condition and convulsions, it seems a matter for concern that such high levels of organochlorine can now be found in the Arctic over 250 miles north of the mainland and in a species which never migrates far south in an area where the surface seawater probably does not even originate in Europe, but in the western North Atlantic.

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PCB Contamination from Boat Bottom Paint and Levels of PCB in Plankton outside a Polluted Area

SAMPLES of zoo- and phytoplankton were collected in Stockholm harbour during an investigation into levels of polychlorinated biphenyls (PCBs). The samples were taken in September and October 1971 and in June 1972 at the localities shown in Fig. 2*a* and *b*. The opportunity was taken to check the possibility that contamination of plankton samples might occur from the anti-fouling paint, containing PCB, used on the boat.

Plankton samples were taken at various locations around the boat in a 0.1 mm mesh net at a trawling speed of about 1 knot. They were analysed within three days of collection. PCB contents were determined in terms of the extractable fat because of the difficulty in determining the true sample weight.

The plankton was homogenized and extracted as described previously[1]; extracted fat was weighed and dissolved in

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