Polychlorinated Biphenyls May Alter Marine Trophic Pathways by Reducing Phytoplankton Size and Production

Abstract. *Polychlorinated biphenyls at concentrations of 1 to 10 micrograms per liter reduced phytoplankton biomass and size in natural estuarine phytoplankton communities grown within dialysis bags in situ in an estuarine marsh. In polychlorinated biphenyls-contaminated waters, these changes could increase the number of trophic levels and divert the flow of biomass from harvestable fish to jellyfish and other gelatinous predators.*

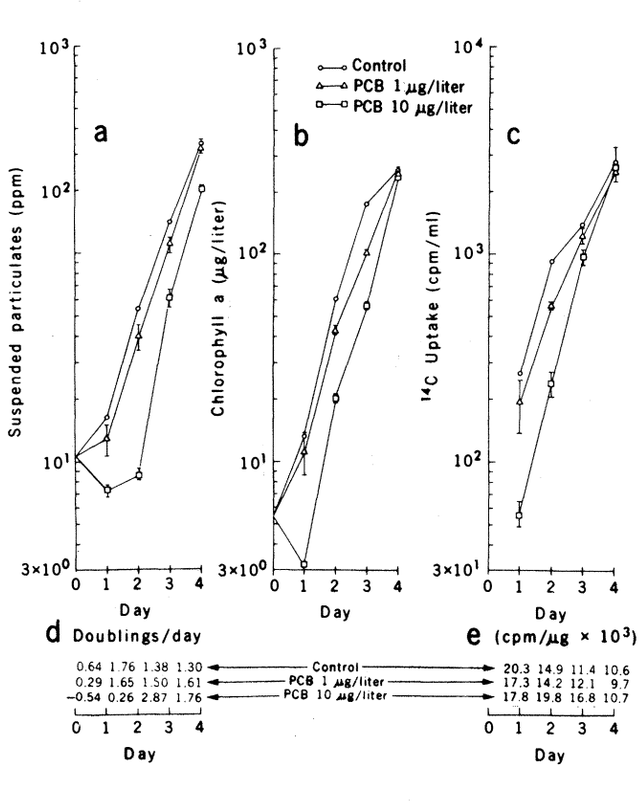
Harvestable marine fish resources are believed to result from an abundance of large phytoplankton at the base of relatively short food chains (*1*, *2*). Small phytoplankton, by contrast, are thought to produce longer food chains, leading to ecosystems containing numerous ctenophores, jellyfish, and other gelatinous predators (*2*).

The relative abundance of large or small phytoplankton has been related to natural variations in nutrient availability, light, mixing, and zooplankton grazing and to man-made pollutants, which stimulate the growth of small phytoplankton (*2*). We report evidence that exposure to polychlorinated biphenyls (PCB's) reduces phytoplankton biomass and size within natural estuarine phytoplankton communities.

The PCB's are widespread pollutants of the marine environment (*3*). Exposure of marine phytoplankton cultures to PCB concentrations of micrograms per liter reduces growth rates of sensitive species (*4*). In mixed cultures, differential sensitivities to PCB's may lead to changes in species composition (*5*).

The use of dialysis membrane chambers permits an evaluation of the impact of pollutants on natural phytoplankton assemblages under conditions closely approximating those found in natural waters (*6*). We measured the effects of PCB exposure on the ^{14}C uptake, chlorophyll a concentration, particle concentration and size distribution (*7*), and species composition of natural phytoplankton assemblages contained in dialysis chambers suspended in natural waters for 4 to 10 days.

Natural phytoplankton assemblages were collected in Flax Pond, a tidal marsh midway along the south shore of Long Island Sound (*8*). To remove large zooplankton herbivores, such as copepods, water was passed through 132-μm nylon mesh, then divided into 1.5-liter portions (six for the experiment of 8 to 12 June 1976 and eight for the experiment of 21 September to 1 October 1976), which were poured into 1-gallon glass jugs. A mixture of PCB's (Aroclor 1254), dissolved in 15 μl of methanol, was diluted 10^5-fold on injection into test jugs; control jugs received an equal volume of methanol (*9*). Each treatment level or control was performed in duplicate. After floating in Flax Pond for 1 hour, the jugs were emptied into dialysis membrane bags permeable to materials with molecular weights lower than 12,000 to 14,000. The bags were inserted into protective polypropylene tubes (2.5-mm mesh) and suspended just below the wa-



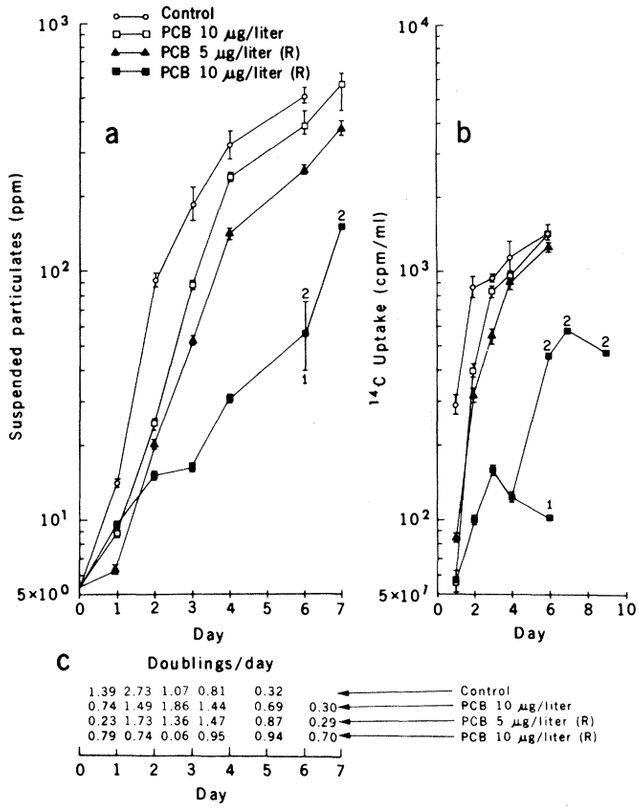


Fig. 1 (left). (a) Suspended particle concentration (parts per million); (b) chlorophyll a concentration (micrograms per liter); (c) ^{14}C uptake (counts per minute per milliliter); (d) suspended particle growth rate (doublings per day) (*16*); and (e) specific ^{14}C uptake (counts per minute per microgram of chlorophyll a) for the experiment of 8 to 12 June 1976. Data points are means of replicate bags (N = 2); bars indicate the range of observations. One control bag was lost on day 1. Fig. 2 (right). (a) Suspended particle concentration; (b) ^{14}C uptake; and (c) suspended particle growth rate (*16*) for the experiment of 21 September to 1 October 1976. Data points are means (N = 2), and bars indicate the range of observations for replicate bags, except that values for each bag treated repeatedly (R) with PCB's at 10 μg/liter are plotted after day 4. Growth rates were calculated by using means for replicate bags.

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ter surface (*6, 10*). Bags were sampled daily thereafter.

In the June experiment, 1 or 10 μg of PCB's was added once (day 0) to each liter of culture (*11*). In September, one pair of cultures was exposed once (day 0) to 10 μg/liter while the other two pairs received daily doses of 5 or 10 μg/liter. All inoculations were performed after transfer of the cultures to jugs, followed by a 1-hour incubation period and return of the cultures to the bags.

Samples were analyzed for photosynthesis (^{14}C assimilation), chlorophyll a content, phytoplankton species composition and particle size (optically), and particle concentration and size distribution (electronically) between 2.45 and 120 μm equivalent spherical diameter (ESD), as previously described (*10*).

Microscopic examination revealed that, among particles larger than 9 μm ESD, June cultures were dominated by the diatom *Rhizosolenia fragilissima*. Other chain-forming diatoms present were *Skeletonema costatum*, *Thalassiosira decipiens*, *Thalassionema nitzchioides*, and *Leptocylindrus* sp. Chains of *Skeletonema costatum* dominated September cultures, with other large diatoms including *Chaetoceros curvisetus*, *C. didymus*, *Stephanopyxis turris*, *Corethron hystrix*, *Leptocylindrus* sp., *Ditylum brightwellii*, and *Eucampia zoodiacus*. A few dinoflagellates of the genus *Peridinium* were also present. Particles smaller than 9 μm ESD in both experiments consisted primarily of small phytoflagellates, with lesser numbers of pennate diatoms and a centric diatom resembling *Thalassiosira pseudonana*.

Suppression of algal growth by PCB's was dose-dependent. Particle concentrations in cultures exposed to a single treatment of PCB's at 1 μg/liter were lower than those in controls for at least 3 days (Fig. 1a), although growth rates (rates of particle formation) recovered more rapidly (Fig. 1d). In cultures exposed to a single treatment with 10 μg/liter or repeated treatment with 5 μg/liter, growth rates took longer to recover (Figs. 1d and 2c), and particle concentrations remained lower than those in controls throughout the experiments (Figs. 1a and 2a).

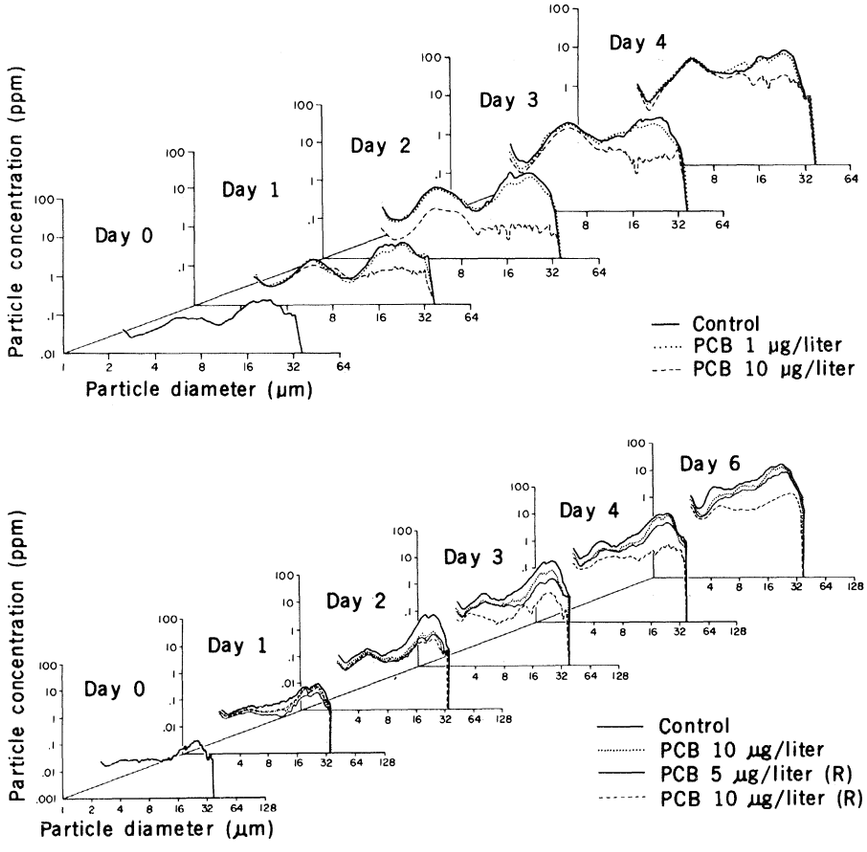

Fig. 3 (top). Particle concentration-size distribution, ranging from 2.45 to 120 μm ESD, for the experiment of 8 to 12 June 1976. The curve for day 0 characterizes the natural particle assemblage before PCB treatment. The distributions for PCB-treated cultures are the means for two replicates; one control bag was lost on day 1. Fig. 4 (bottom). Particle concentration size distribution, ranging from 2.45 to 120 μm ESD, for the experiment of 21 September to 1 October 1976. The curve for day 0 characterizes the natural particle assemblage before PCB treatment. Distributions are the means for two replicates.

Repeated treatment with 10 μg/liter ultimately destroyed algal cultures. A decline in ^{14}C photosynthetic uptake was evident after 3 to 6 days (Fig. 2b), and visual inspection showed that moribund cells, algal detritus, and bacteria dominated the cultures. Moreover, in both June and September, cultures treated with 10 μg/liter exhibited clumped cytoplasms, misshapen nuclei and chloroplasts, and other morphological abnormalities.

Incorporation of ^{14}C was temporarily suppressed in all PCB-treated cultures (Figs. 1c and 2b), but only in cultures treated daily with PCB's at 10 μg/liter did carbon fixation remain consistently lower than in controls. Although chlorophyll a synthesis in cultures exposed once to 1 or 10 μg/liter was inhibited for 3 to 4 days (Fig. 1b) (*12*), PCB's had little effect on chlorophyll function, since ^{14}C incorporation per microgram of chlorophyll a was not consistently lower in PCB-treated than in control cultures (Fig. 1e).

All sizes of algae were not equally affected. In June, treatment of algal communities with PCB's at 1 μg/liter suppressed the growth rate of particles larger than 9 μm ESD for 3 days, but the growth rate of smaller particles was unaffected (Fig. 3). Treatment with 10 μg/liter suppressed the numbers of particles larger than 9 μm ESD by about an order of magnitude for 3 to 4 days, while concentrations of smaller particles recovered within 3 days. In September, suppression of particle concentration by PCB's was evident in all size classes, but was proportionately greater for particles larger than 9 μm ESD, especially on day 2 for all treated cultures and throughout the experiment for cultures treated repeatedly with 10 μg/liter (Fig. 4).

Suppression of particles larger than 9 μm ESD suggests that large diatoms are more sensitive to PCB's than smaller algae. Whereas earlier work demonstrated that PCB's can alter the total biomass and the species composition of phytoplankton assemblages (*5, 10*), the work reported here demonstrates that phytoplankton size can also be reduced when large algal species are eliminated by PCB's. Dieldrin, another chlorinated hydrocarbon, also selected for smaller cells and reduced biomass in a single-species culture (*13*).

Many zooplankters are selective grazers, often choosing food on the basis of size, shape, and species (*14*). If algal cells are too small, they may not be grazed efficiently by common estuarine and coastal copepods (*15*).

A two-pathway hypothesis has been

proposed for the transfer of biomass through marine food webs (*2*). One pathway leads from large phytoplankton by way of a one- to three-step food chain to fish that can be harvested by humans (*1*). The other leads from smaller phytoplankton through about five trophic levels to various gelatinous predators (*2*).

If this hypothesis is valid, then PCB pollution of coastal waters could result not only in PCB-contaminated fish products and diminished primary and secondary production, but also in ecosystems reduced in harvestable fish through a reduction in phytoplankton size and associated alteration of the natural food web.

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Thermal Sensitivity in Lichens

Abstract. *Lichens are believed to be extremely resistant to high-temperature stress when desiccated. Results from a reexamination of this concept indicate that some air-dry lichen thalli can be extremely sensitive to even moderate levels of heat stress whereas others exhibit a considerable degree of heat resistance. These differential levels of thermal resistance correlate exactly with the ecology of these populations.*

It has long been believed that lichens are resistant to high-temperature stress (*1*). This idea is based on evidence presented by Lange (*2*), who examined the heat resistance of 40 species of lichens. The temperature that caused a reduction in the normal respiration rate of air-dry thalli by one-half was accepted as an index of the limit of heat resistance, and these indices ranged from 70°C in *Alectoria sarmentosa* to 101°C in *Cladonia pyxidata*. However, hydrated lichen thalli did not differ from other kinds of plant tissue and their limits of heat resistance ranged from 35° to 46°C. We have reexamined thermal sensitivity in two lichen populations and found that in fact dry lichen thalli can be extremely sensitive to even moderate levels of heat stress. Conversely, other populations, collected from a contrasting environment, exhibited a considerable degree of heat resistance when in the air-dry state. These differential levels of thermal sensitivity correlate exactly with the ecology of the two populations.

Replicate thalli of *Peltigera canina* var. *praetextata* were collected in the air-dry state from deciduous woodland in southern Ontario and *P. canina* var. *rufescens* from an open xeric roadside habitat in central Ontario. The material was

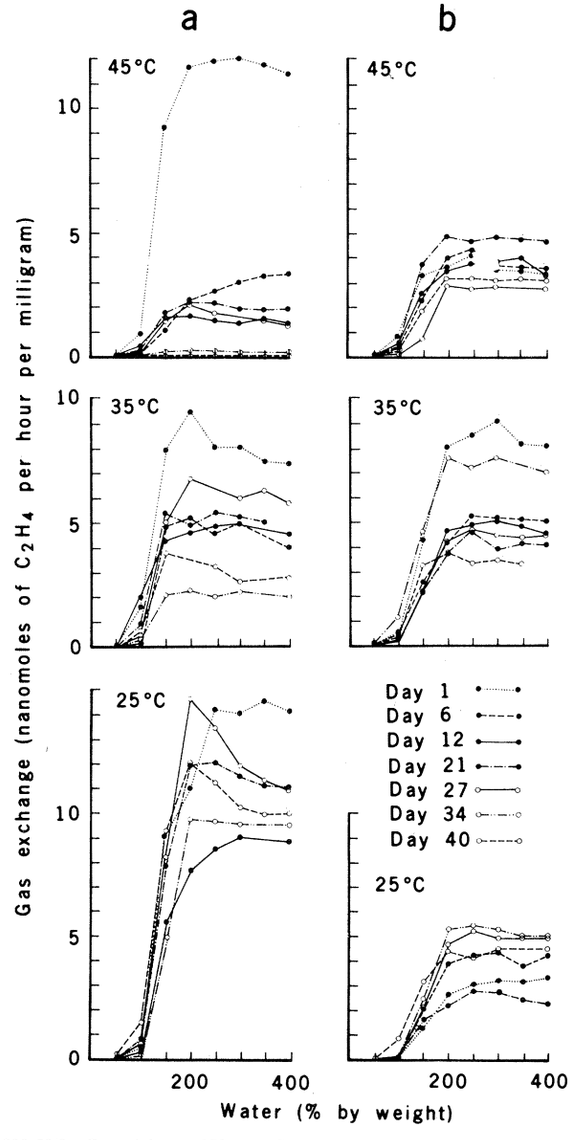

Fig. 1. The nitrogenase activity of (a) *Peltigera canina* var. *praetextata* and of (b) *Peltigera canina* var. *rufescens* after air-dry storage at temperatures of 25°, 35°, and 45°C. Thallus saturation is expressed as a percentage of the final oven dry weight of each replicate.

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