egg per cob or water hole; if this were not the case even extreme selfishness could not be favoured by selection. *Heliothis* seems to have this habit in nature[11] in spite of a contrary impression given by Kirkpatrick[11]. But why, if the model is correct, are more convincing examples of spite hard to find? First, I suggest, because all actions do cost something. Second, because an animal will not normally have any way of recognizing which other members of its species have less than average relationships. Memory, local odour, and nearness to place of birth may permit recognition of close relatives, but this leaves a remainder whose average relationship will be only very slightly less (in large populations) than the total average. Moreover, with common patterns of dispersal the unrecognized individuals most likely to be encountered are the ones likely to be most related. Third, because single populations that are so small in "effective size" as to have b_i generally much different from zero must be in a precarious position already, and the selection of a gene causing spite can only hasten their extinction. If, on the other hand, there is a composite population made up of many such small precarious elements, either we must recognize a process of group selection in which those elements that have not yet been overwhelmed by selfish and spiteful mutations replace those that have, or we must consider relationship against the background of the total population, as seems the natural point of view if the subpopulations are emitting and receiving migrants.

Taken together these points suggest that my previous account is not seriously inaccurate for social behaviour in realistic circumstances. The point that has now been brought into focus, the adaptiveness of selfishness and spite in panmictic populations, suggests one reason why panmixia hardly occurs. When it does occur, the selection of selfish traits reduces mean fitness and the population is forced to retreat from its less favourable habitats. If it remains panmictic the trend may continue and lead to extinction. If, on the other hand, the population breaks into isolates as population declines, a breeding structure may be achieved in which further spread of selfishness, and hence further decline, can be resisted.

W. D. HAMILTON

Imperial College Field Station,
Silwood Park,
Ascot, Berks.

Received February 6; revised July 16, 1970.

[1] Hamilton, W. D., *Amer. Nat.*, **97**, 354 (1963).
[2] Hamilton, W. D., *J. Theor. Biol.*, **7**, 1 (1964).
[3] Hamilton, W. D., in *Man and Beast: Comparative Social Behaviour* (Proc. Smithsonian Institution Third Intern. Symp., 1969) (in the press).
[4] Price, G. R., *Nature*, **227**, 520 (1970).
[5] Wright, S., *Amer. Nat.*, **56**, 330 (1922).
[6] Wright, S., *Genetics*, **16**, 97 (1931).
[7] Wright, S., *Ann. Eugenics*, **15**, 323 (1951).
[8] Wright, S., *Bull. Amer. Math. Soc.*, **48**, 223 (1942).
[9] Orians, G. H., and Wilson, M. F., *Ecology*, **45**, 736 (1964).
[10] Marshall, A. J., *Bowerbirds* (Oxford Univ. Press, 1954).
[11] Corbet, P. S., and Griffiths, A., *Proc. Roy. Entomol. Soc.*, A, **29**, 125 (1954).
[12] Kirkpatrick, T. W., *Insect Life in the Tropics* (Longmans, London, 1957).
[13] Walker, M. G., *Canad. J. Res.*, **20**, 294 (1942).

Source of Polychlorinated Biphenyl Contamination in the Marine Environment

SINCE residues of polychlorinated biphenyls (PCBs) were identified in Swedish wildlife[1], they have been reported in many marine species[2-7]. Samples of marine fish and molluscs from Scottish waters have been analysed for organochlorine residues at this laboratory on several occasions since 1965, and the concentrations of PCB residues detected in these samples have been generally highest from the Firth of Clyde. Therefore a wide variety of samples from this area was used in the autumn of 1969 to try to establish the route by which the PCB residues reached the fish. Samples of the water surface film and sub-surface water were taken at various points in the estuary, and also at 2-mile intervals along the river to the centre of Glasgow, to detect any local discharges containing PCBs. No PCB residues could be found (limit of detection in water, 1 part in 10^{11}) and samples of effluents discharged from trunk sewers into the estuary and in the Glasgow area also showed no significant concentrations of PCBs. Concentrations in zooplankton by comparison were less than 0·03 p.p.m. (3 parts in 10^8), and in clupeoid fish up to 2·6 p.p.m. (both expressed on a wet weight basis).

Polychlorinated biphenyls are produced by the controlled chlorination of biphenyl, and are made available for industrial use in various forms, mostly as liquids of different viscosities, according to the degree of chlorination. More than 200 compounds are theoretically possible, and each commercial preparation contains several individual PCBs with different arrangements of the chlorine atoms in the molecule. PCB compounds found in wildlife samples, using gas liquid chromatography at about 200° C, have been shown to contain mostly six to seven chlorine atoms[4], although compounds with more chlorine atoms may not be sufficiently volatile to be detectable at this temperature. For comparison with the PCB residues found in wildlife, a PCB mixture containing about 50 per cent by weight of chlorine is commonly used as a reference (for example, 'Aroclor 1254', Monsanto Ltd).

In Britain, effluents from industry apart from those which are unacceptable are usually passed to sewage purification works for treatment with domestic sewage. Samples of crude sewage sludge from such works in Glasgow and adjacent areas have been analysed for PCBs. The sludge from this area is transported by boats to the estuary and dumped in deep water 6 miles south of Garroch Head (Isle of Bute), at the rate of about a million wet tons per year. It can therefore constitute a source of entry into the marine environment of some industrial waste products.

Table 1. RELATIVE PEAK HEIGHTS IN GAS-LIQUID CHROMATOGRAMS

R_s	69	81	100*	121	145†	171	200	204	203	233	370
Sample											
Raw sludge *A*	38	69	51	104	100	92	22	19	21	10	6
Raw sludge *B*	20	24	17	51	100	66	70	53	64	29	25
'Aroclor 1254'	20	73	59	110	100	92	26	12	19	5	4
'Aroclor 1260'	8	14	4	30	100	66	70	54	57	30	23

* This peak includes *pp'*-DDE in sludge.
† Peak height = 100 for reference.

Although the extraction of organochlorine compounds from sewage solids (using a mixture of *n*-hexane and isopropanol) is believed to be less efficient than extraction from water, it was nevertheless found that many of the sludge samples gave gas-liquid chromatograms similar to those of PCB mixtures. Table 1 shows the proportions (in terms of relative peak heights) of the major peaks in typical chromatograms, as identified by their R_s values (retention time at 200° C relative to dieldrin = 100). The column used was packed with 10 per cent DC-200 silicone on 'Chromosorb W'. PCB compounds were separated from all major organochlorine pesticide residues, except *pp'*-DDE, on silica columns[8]. The peak pattern for sludge *A* is closely similar to that of a PCB formulation containing about 50 per cent by weight of chlorine (for example, 'Aroclor 1254'), but the pattern for sludge *B* suggests that it contains those PCBs of higher chlorine content in a greater proportion than *A*, and is similar to the pattern produced by 60 per cent chlorinated products (for example, 'Aroclor 1260').

On the basis of wet weight of crude sludge the estimated concentrations of PCBs, using 'Aroclor 1254' as reference, in fifteen samples were in the range < 0·1 to 14 p.p.m. (If 'Aroclor 1260' is used as reference, the concentrations

DSW 029286

STLCOPCB4013248

are somewhat lower.) In terms of dry matter the values ranged from 1 to 185 p.p.m. (values uncorrected for extraction efficiency). The various plants were each sampled on three occasions, and two plants were found to give consistently high concentrations of PCB (50–160 p.p.m. dry weight). The liquid effluents from these plants contained comparatively insignificant concentrations of PCB. It has proved impossible to locate the origins of the PCB discharges to the sewage plants concerned, because several hundred factories are linked to the sewers. The chemicals can be used for many industrial purposes[5], but it is not known how many of the possible uses are exploited in the Glasgow area.

It thus seems possible that the PCBs in the Clyde ecosystem result from routine dumping of crude sewage sludge from treatment works in Glasgow and adjacent areas. An average concentration of PCB of the order of 1 p.p.m. (as found in fifteen samples of wet sludge weighted according to the proportions dumped) would be equivalent to a discharge in the Clyde estuary of the order of 1 ton of PCBs per year. Four samples of crude sludge from Manchester (dumped in the Northern Irish Sea), which were analysed at the Burnham-on-Crouch Laboratory of the Ministry of Agriculture, Fisheries and Food (personal communication from J. E. Portmann) using similar techniques, contained between 0·1 and 5 p.p.m. (wet weight) of PCBs. If there is an average of 2 p.p.m. dumped at a rate of 0·5 million tons of sludge per year, about 1 ton of PCB isomers per year would be discharged. Analyses by the same laboratory of samples of London sewage sludge have shown that these contain less PCB, typically of the order of 0·2 p.p.m. About 5 million tons are dumped off the Thames' Estuary, again equivalent to about a ton of PCB isomers.

Where this form of sludge disposal is practised, the introduction of PCBs from industrial wastes is clearly possible. Some coastal towns, however, discharge combined sewage and industrial wastes direct to the sea without treatment, and in such cases any PCBs present could be expected to enter the ecosystem adsorbed to suspended solids. The disposal of sewage sludge on land, as practised in inland areas, could lead to the introduction of PCB residues into the terrestrial ecosystem by transfer through food chains. So far, however, no PCB residues have been detected in freshwater fish in Scotland at this laboratory.

I thank the City of Manchester Rivers Department and the Scientific Branch of the Greater London Council for sewage samples.

A. V. HOLDEN

Freshwater Fisheries Laboratory,
Pitlochry,
Scotland.

Received August 18, 1970.

1 Jensen, S., *New Scientist*, **32**, 612 (1966).
2 Holden, A. V., and Marsden, K., *Nature*, **216**, 1274 (1967).
3 Risebrough, R. W., Riseche, F., Peakall, D. B., Herman, S. G., and Kirven, M. N., *Nature*, **220**, 1098 (1968).
4 Koeman, J. H., Ten Noever de Brauw, M. C., and de Vos, R. H., *Nature*, **221**, 1126 (1969).
5 Holden, A. V., *ICES C. M. 1969 Fisheries Improvement Committee*, Document No. 2: 22 (mimeo) (1969).
6 Jensen, S., Johnels, A. G., Olsson, M., and Otterlind, G., *Nature*, **224**, 247 (1969).
7 *Nature*, **224**, 602 (1969).
8 Holden, A. V., and Marsden, K., *J. Chromatog.*, **44**, 481 (1969).
9 Reynolds, L. M., *Bull. Env. Contam. and Toxicol.*, **4**, 128 (1969).

Relationship between Egg Size and Post-hatching Chick Mortality in the Herring Gull (*Larus argentatus*)

In many gull species, the third laid egg of the typical three egg clutch is distinctly smaller than the first two[1,2].

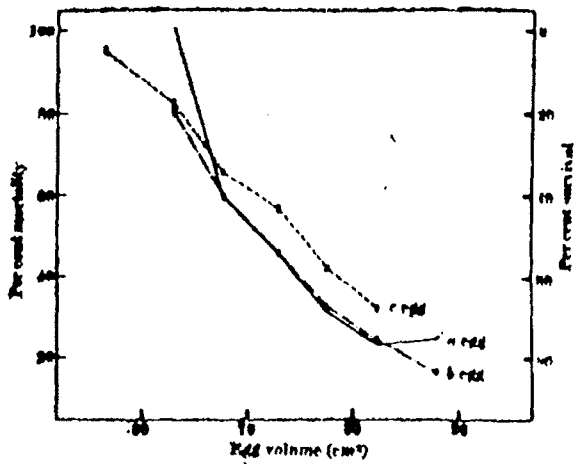

Fig. 1. The relationship between egg volume and post-hatching chick mortality/survival for each egg of the laying sequence.

In the herring gull (*Larus argentatus*), the chick hatching from this third egg suffers a much higher mortality than either of its siblings[3], although the hatching success is the same for all three eggs. In a series of egg transfer experiments carried out on the Isle of May, Scotland, it has been possible to demonstrate at least two factors contributing to this differential mortality, namely the size disadvantage and the sequence of hatching, because third laid eggs normally hatch last. Although the survival of chicks from third eggs increased when they were the first to hatch, it was still lower than that of its siblings.

To investigate this problem further, a detailed field study was made of the post-hatching survival of herring gull chicks from more than 1,400 eggs of known volume[4,5]. The survival of the chicks was followed by leg banding at hatching. Most of the mortality occurred in the first week after hatching[6], and the mortality after that time was independent of the size of the egg from which the chick hatched. The fate of chicks within the first seven days of life was therefore grouped according to egg volume and sequence of laying (see Table 1 and Fig. 1).

Table 1. CHICK MORTALITY WITHIN A WEEK OF HATCHING COMPARED WITH CALCULATED EGG VOLUME

	Egg volume cm³						
	60–65	65–70	70–75	75–80	80–85	85–90
a egg							
No. hatched	—	4	92	79	96	94	90
No. died	—	4	19	66	27	22	10
Per cent mortality	—	100	50·4	45·6	21·4	23·4	25
b egg							
No. hatched	—	10	42	87	90	78	86
No. died	—	8	25	46	21	10	4
Per cent mortality	—	80	59·5	46·0	23·3	24·4	10·0
c egg							
No. hatched	10	90	96	92	86	10	—
No. died	17	49	22	53	23	5	—
Per cent mortality	94·4	81·7	64·8	56·5	41·8	31·9	—

For each egg of the laying sequence (referred to as the *a*, *b* and *c* eggs), there is a significant positive correlation between egg size and chick survival ($P < 0{\cdot}001$), giving a range from approximately 80 per cent to 10 per cent survival. This relationship is similar for the first two eggs in a clutch, but although the slope is the same for the third egg, the survival is 10 per cent lower for eggs of the same size. Thus the survival of the third hatched chick is lower than would be expected from its size, but the most important factor in determining post-hatching survival is the size of the egg. Nearly all the chicks from eggs smaller than 65 cm³ died soon after hatching. Only 8 per cent of all eggs laid were below this size, and 89 per cent of these were *c* eggs.

Egg size is positively correlated with several factors including yolk weight and lipid (hexane soluble) content, as it is in other species[7]. Furthermore, the weight of

DSW 029287

STLCOPCB4013249