

RESULTS

Between February 1994 and April 28, 1999 (5 years and 2 months) PEQAP has monitored 1,107 commercial layer flocks. Over 85% of the Pennsylvania layer industry are enrolled in PEQAP representing 23,929,600 hens (April 28, 1999). A total of 450 (41%) and 657 (59%) of these flocks, respectively were housed in single stand alone houses versus complex houses. Overall 154 flocks (13.9%) had positive environments.

***S. enteritidis* environmental positive flocks.** In single houses 44 (9.8%) flocks and in complexes 110 (16.7%) flocks had *S. enteritidis* isolated from the environment. As a proportion of all *S. enteritidis* positive sampling periods in single houses, 18 flocks (40.9%) had their 30 week test and 26 flocks (59.1%) had their 45 week and post molt environmental tests *S. enteritidis* positive. In contrast, hens housed in complexes had 83 flocks (75.5%) with their 30 week test and 27 flocks (24.6%) had their 45 week and post molt tests *S. enteritidis* positive. The individual percent of flocks environmentally positive for *S. enteritidis* by each sample period is given in (Fig. 1). Individual proportions of flocks environmentally positive for *S. enteritidis* which housed 2 or less flocks or 3 or more flocks as housed in single stand alone houses or in complexes is noted in (Fig. 2) and (Fig. 3), respectively.

***S. enteritidis* positive eggs.** A total of 933,900 eggs were cultured for *Salmonellae* from 1,335 collections from 154 *S. enteritidis* environmental positive flocks. *S. enteritidis* was isolated from 146 eggs. The overall prevalence of *S. enteritidis*-contaminated eggs from environmentally positive flocks was 1.6 eggs/10,000 eggs sampled. In single stand alone houses 236,510 eggs were cultured from 376 collections from 44 *S. enteritidis* environmental positive flocks. *S. enteritidis* was isolated in 47 eggs from 17 flocks for a prevalence of *S. enteritidis*-contaminated eggs of 2.0 eggs/10,000 eggs sampled. The number of flocks and their associated number of positive egg pools are depicted in Table 2. In contrast, in complex houses 697,390 eggs were cultured from 959 collections from 110 *S. enteritidis* environmental positive flocks. *S. enteritidis* was isolated in 99 eggs from 35 flocks for a prevalence of *S. enteritidis*-contaminated eggs of 1.4 eggs/10,000 sampled. The number of flocks and their associated number of positive egg pools are depicted in Table 3.

Temporal comparison of *S. enteritidis* in replacement flocks. In total, 70 houses that had flocks monitored in PEQAP as of December 31, 1994 were compared with the same 55 remaining houses which housed replacement flocks as of April 28, 1999. These flocks were originally enrolled in the *Salmonella enteritidis* Pilot Project (April 1992 to January 1994). Approximately 50% of the flocks in the *S. enteritidis* Pilot Project were *S. enteritidis* environmentally positive (5). The remaining 15 flocks discontinued in PEQAP, primarily as result of going out of business.

Overall 18 of 70 flocks (25.7%) as of December 31, 1994 were *S. enteritidis* environmentally positive. In total, 68 of 190 (35.8%) of environmental samples collected from these 18 flocks were positive for *S. enteritidis*. These comparisons are noted in (Fig. 4). Of the 70 flocks, 34 were housed in single stand alone houses and 36 in

complexes. Ten of the 34 flocks (29.4%) in single houses were *S. enteritidis* positive. There were 28 of 98 environmental samples (28.6%) from these flocks positive for *S. enteritidis*. Eight of the 36 flocks (22.2%) in complexes were *S. enteritidis* positive. There were 40 of 92 environmental samples (43.5%) from these flocks positive for *S. enteritidis*.

Overall 4 of 55 flocks (7.3%) as of April 28, 1999 were *S. enteritidis* environmentally positive. In total, 10 of 46 (21.7%) of environmental samples collected from these 4 flocks were positive for *S. enteritidis*. These comparisons are noted in (Fig. 4). Of these 55 flocks, 23 were housed in single-stand-alone houses and 32 in complexes. None of the 23 flocks (0.0%) in single houses were *S. enteritidis* positive. Four of the 32 flocks (12.5%) in complexes were *S. enteritidis* positive.

Comparison of human *S. enteritidis* isolation rates. Table 1 depicts individual human *Salmonella enteritidis* isolation rates per 100,000 population for the States (Pennsylvania, Maryland, New Jersey, New York) which Pennsylvania is the principal supplier of shell eggs. Between 1989 and 1997 there was a 50.0%, 48.6%, 55.4%, and 43.5% reduction in rates, respectively. The combined reduction rate for all four states was 49.4%.

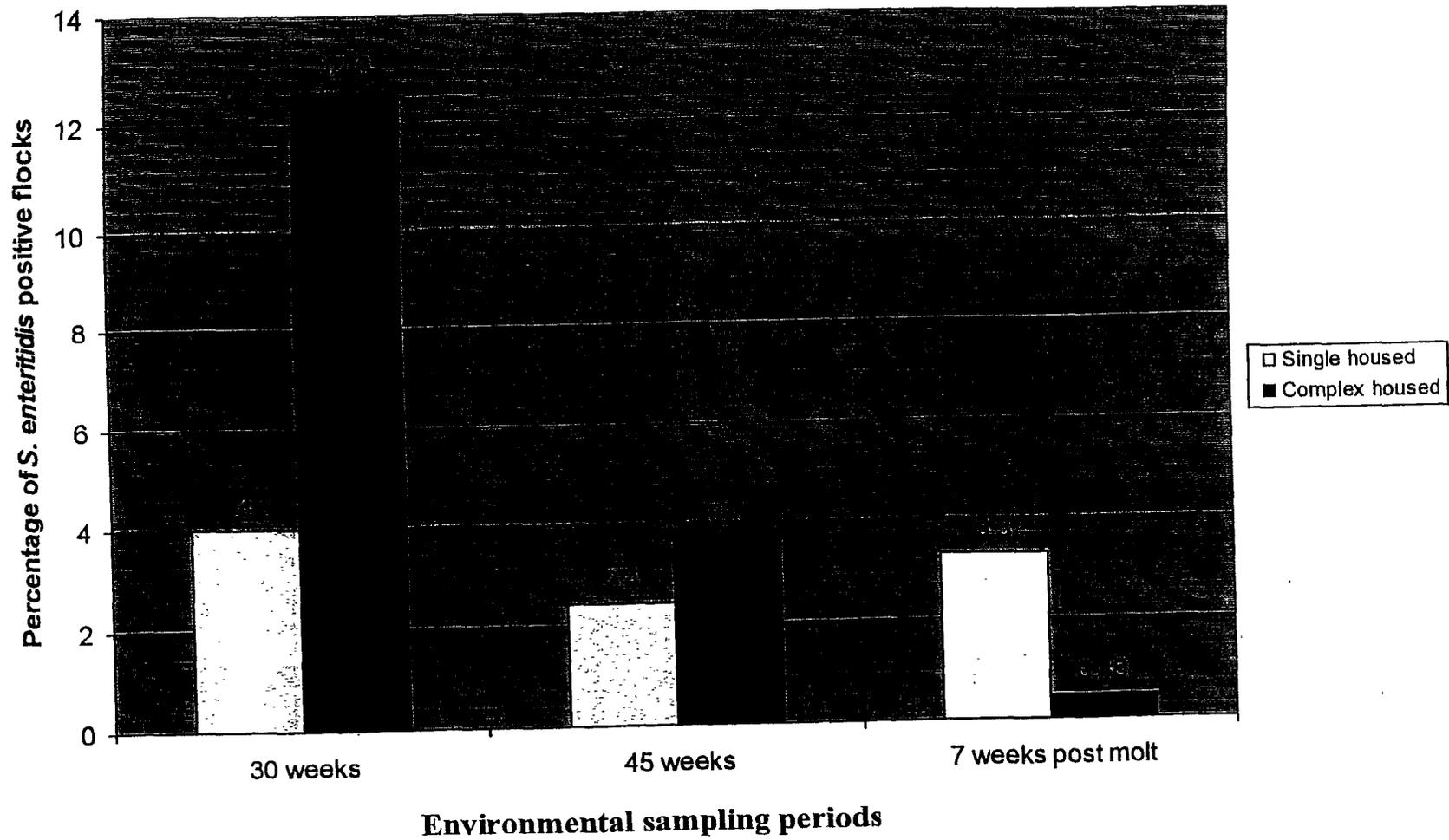


Fig. 1. Percent of *S. enteritidis* positive flocks housed as single - stand alone flocks and in complexes by environmental sampling periods (30 wk, 45 wk, and 7 wk post molt) in PEQAP.

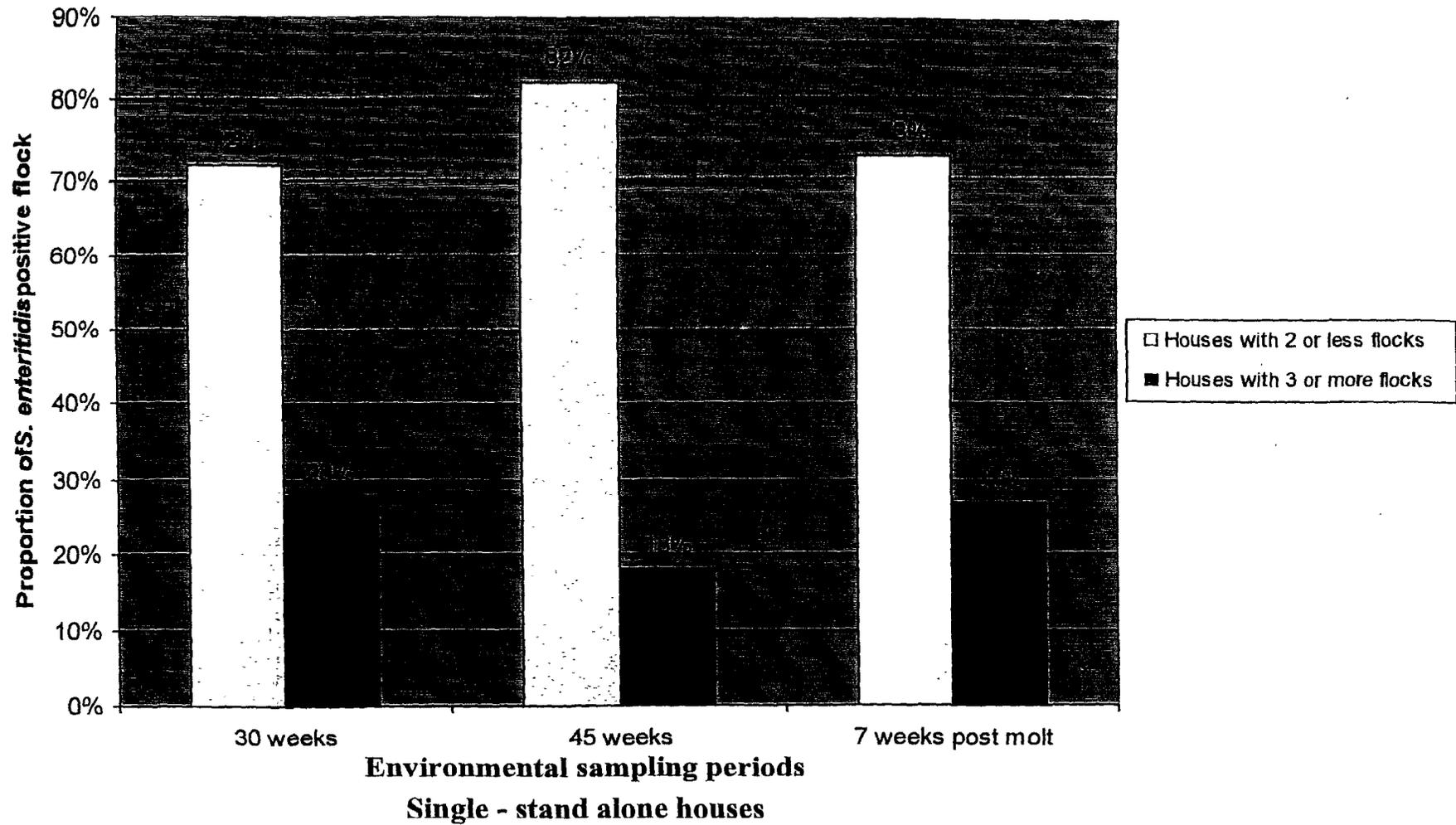


Fig. 2. Proportion of *S. enteritidis* positive flocks housed in single - stand alone houses which housed 2 or less flocks or 3 or more flocks by environmental sampling periods (30 wk, 45 wk, 7 wk post molt) in PEQAP.

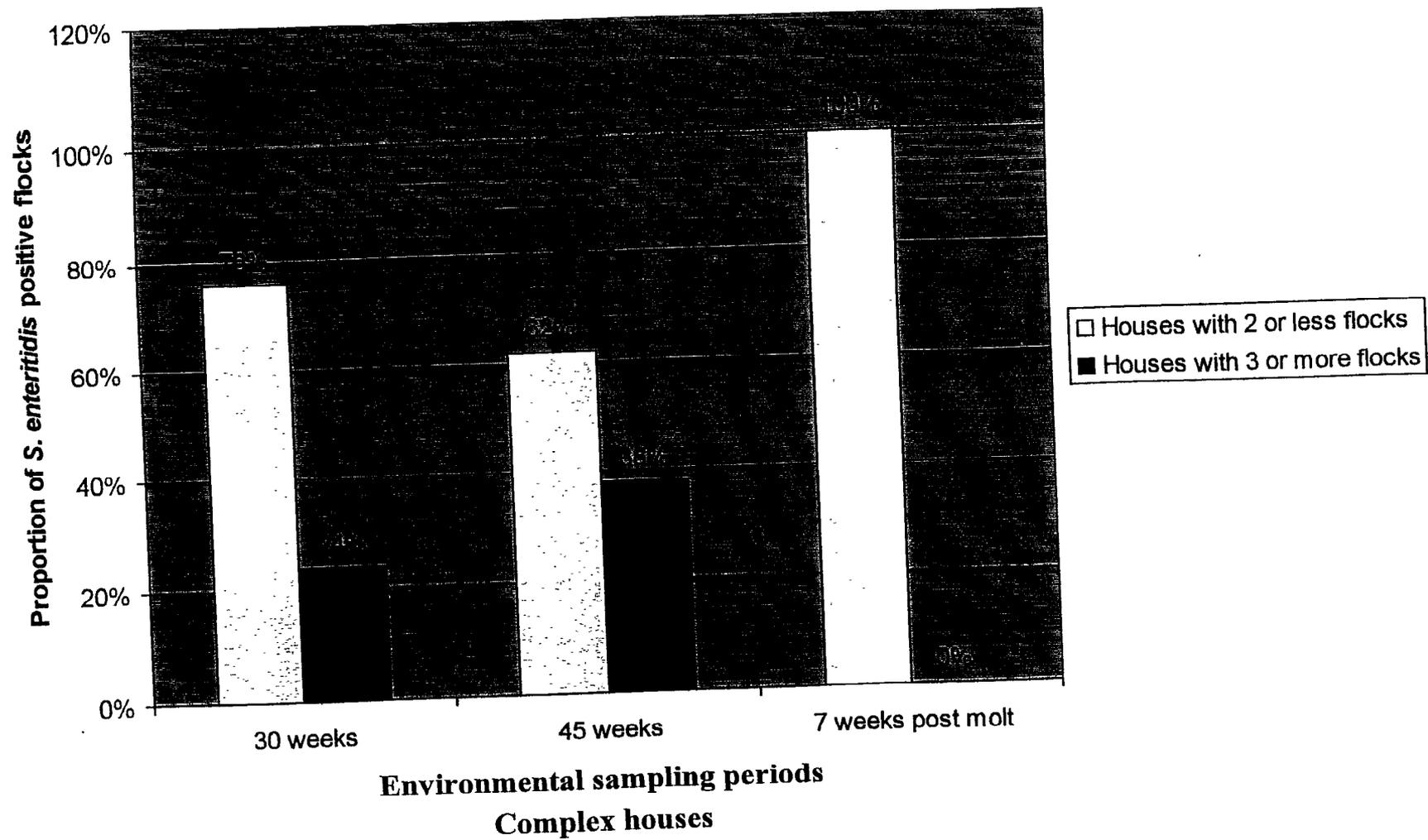


Fig. 3. Proportion of *S. enteritidis* positive flocks housed in complex houses which housed 2 or less flocks or 3 or more flocks by environmental sampling periods (30 wk, 45 wk, and 7 wk post molt) in PEQAP.

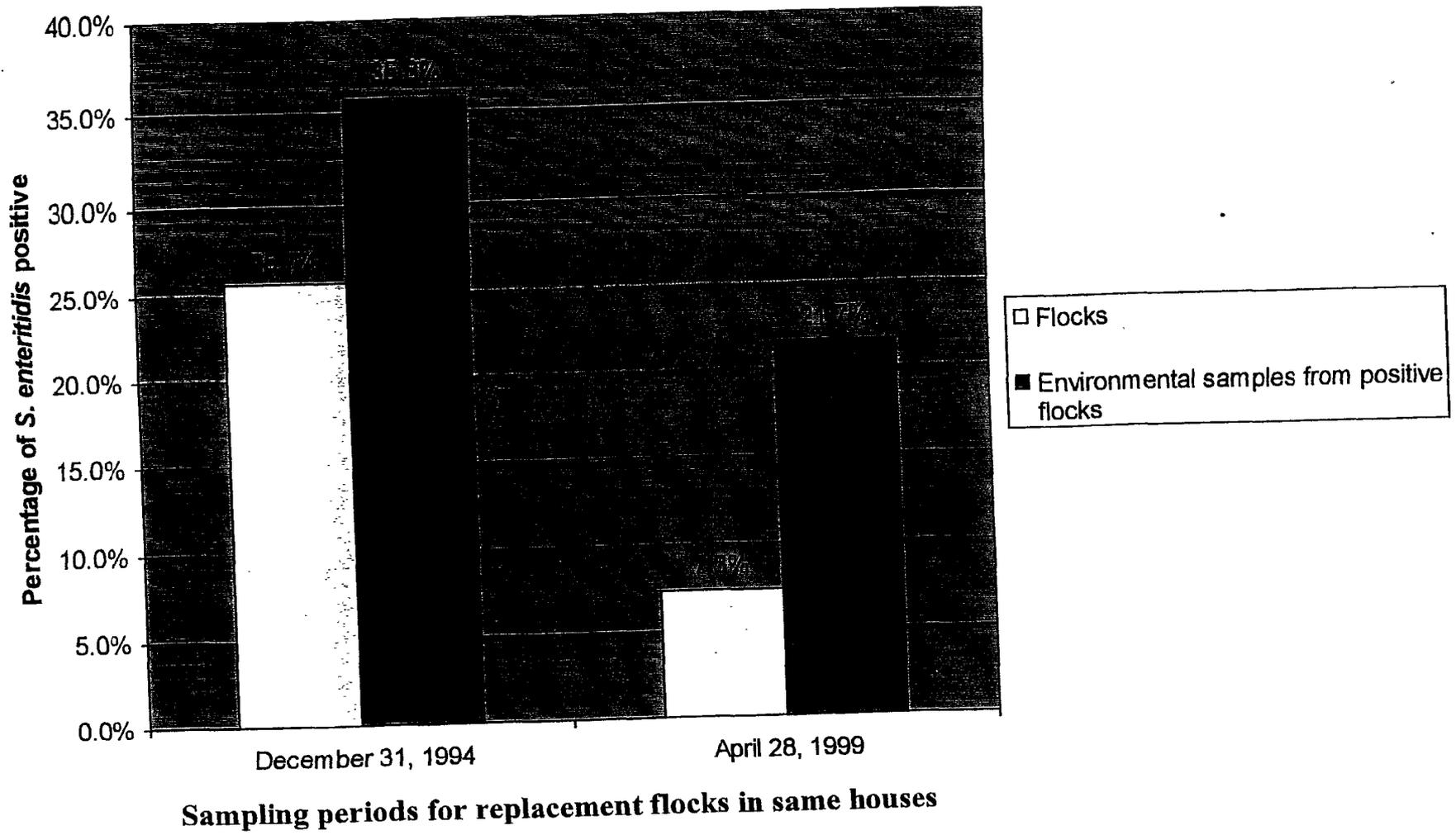


Fig. 4. Percentage of *S. enteritidis* positive flocks and environmental samples by sampling periods (December 31, 1994 and April 28, 1999) for replacement flocks in same houses in PEQAP.

Table 1. Human *Salmonella enteritidis* isolation rates per 100,000 population for the States (Pennsylvania, Maryland, New Jersey, New York) which Pennsylvania is the principal supplier of shell eggs.

Year of Isolation	Pennsylvania	Maryland	New Jersey	*New York
1988	8.4	11.7	10.2	7.2
1989	10.4	10.9	13.9	9.2
1990	8.8	11.9	10.6	8.3
1991	7.9	8.6	12.5	7.5
1992	6.4	7.8	6.5	6.9
1993	5.5	7.7	6.2	6.3
1994	6.6	9.7	7.8	6.1
1995	7.5	8.6	9.2	6.6
1996	6.8	7.6	5.9	6.5
1997	5.2	5.6	6.2	5.2

Source: CDC * Includes New York City

Table 2. Flocks housed in single stand-alone houses which produced *Salmonella enteritidis* positive eggs from a total of 236,510 eggs cultured from 1994 to April 28, 1999 in PEQAP.

	Number of Flocks	Number of Positive Egg Pools
	6	1
	3	2
	1	3
	5	4
	2	6
Total	17	47

Table 3. Flocks housed in complexes which produced *Salmonella enteritidis* positive eggs, from a total of 697,390 eggs cultured from 1994 to April 28, 1999 in PEQAP.

	Number of Flocks	Number of Positive Egg Pools
	15	1
	10	2
	1	3
	2	4
	4	5
	1	7
	1	10
	1	16
Total	35	99

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DISCUSSION

Flocks housed in single stand alone houses had 9.8% of their environments contaminated with *S. enteritidis* as compared with 16.7% of flocks housed in complexes. Complex housed flocks were 1.7 times more frequently contaminated than single houses. Difficulties associated with isolation of individual houses in complexes likely contribute to this higher contamination level. Rodent control is more difficult in multiple house facilities and the lack of all-in-all-out management usually allows for other *S. enteritidis* contaminated flocks present while a particular flock is taken out of a house as spent hens (4). As the cleaning and disinfection of the house containing a positive flock is ongoing and as new pullets are subsequently placed in the disinfected house, workers are traveling amongst all flocks. The risk this presents for transmission of *Salmonella* is not quantified. Ventilation systems continue to exhaust air containing feathers and airborne bacteria, possibly serving as a source of *Salmonellae* contamination of *S. enteritidis* clean hens or at least their environments. Likely horizontal transmission of *S. enteritidis* through airborne methods has been demonstrated in small-scale research facilities (2). The ecology of the *S. enteritidis* bacterium and its spread within commercial flocks is not well documented. These factors multiply the difficulty of actual elimination of *S. enteritidis* from multiple house facilities as these data suggest from surveillance of 1,107 commercial chicken layer flocks over greater than 5 years (Figs. 1,3).

In single houses 4.0% of the flocks had the first environmental samples (30 wk period) *S. enteritidis* positive as compared to 12.6% of complex housed flocks (Fig. 1). Hence, complex flocks were 3.2 times more frequently positive for *S. enteritidis* early in their production cycle. As a percentage of any positive *S. enteritidis* isolation among the individual sampling periods, 18 of 44 (40.9%) flocks housed in single houses versus 83 of 110 (75.5%) flocks housed in complexes respectively, had their 30 wk test positive. These data further reflect the difficulties with limiting exposure and contamination of multiple housed flocks.

Regardless of either single stand alone or complex housing types, flocks that have been long-term enrolled in the Pennsylvania Egg Quality Assurance Program were proportionately likely across any sampling period to have less *S. enteritidis* isolated (Fig. 2 and Fig. 3). In single houses with 3 or more flocks: 5 of 18-30 wk tests, 2 of 11-45 wk tests, and 4 of 15-7 wk post molt tests were *S. enteritidis* positive. This compares with: 13 of 18-30 wk tests, 9 of 11-45 wk tests, and 11 of 15-7 wk post molt tests were *S. enteritidis* positive in houses with 2 or less flocks. In complex houses with 3 or more flocks: 20 of 83-30 wk tests, 9 of 24-45 wk tests, and 0 of 3-7 wk post molt tests were *S. enteritidis* positive. This compares with: 63 of 83-30 wk tests, 15 of 24-45 wk tests, and 3 of 3-7 wk post molt tests were *S. enteritidis* positive in houses with 2 or less flocks.

During the more than 5 years PEQAP is in existence producers have submitted 933,900 eggs for culture of *S. enteritidis*. An overall prevalence of 1.6 eggs/10,000 eggs produced is considerably lower than a prevalence of 2.8 eggs/10,000 from a total of 647,000 visibly clean eggs cultured in the duration of the *Salmonella enteritidis* Pilot

Project (5). This 1.8 times higher level of contamination in the *Salmonella enteritidis* Pilot Project was likely due to the much greater level of *S. enteritidis* positive flocks as determined by environmental culturing. Approximately 50% of Pennsylvania layer flocks enrolled in the *Salmonella enteritidis* Pilot Project were environmentally positive (5) as compared with an overall 13.9% of the flocks in PEQAP.

As a subset of the 1,107 commercial chicken layer farms monitored in PEQAP, 70 flocks and 55 flocks respectively, as of December 31, 1994 and April 28, 1999 were evaluated for the *S. enteritidis* status of their environments and the quantification of number *S. enteritidis* positive environmental samples. A marked 3.5 fold reduction in the number of replacement flocks environmental *S. enteritidis* positive is apparent from 25.7% as of December 31, 1994 to 7.3% as of April 28, 1999. Similarly, for the same time period a reduction of 1.6 fold in the number of environmental samples in these flocks positive for *S. enteritidis* from 35.8% to 21.7%. This reduction is more dramatic considering these houses maintained flocks which were approximately 50% *S. enteritidis* environmentally positive in the *Salmonella enteritidis* Pilot Project from April 1992 through January 31, 1994 (5). Flocks which had 50% and greater of manure samples positive for *S. enteritidis* were 10 times as likely to produce *S. enteritidis*-contaminated eggs as were flocks with a low level of manure contamination (3). Hence, reduction of both *Salmonella enteritidis* positive flocks and the number of positive samples below this key threshold, significantly reduce the likelihood of producing contaminated eggs.

These data clearly demonstrate the overall reduction in *Salmonella enteritidis*, in both the number of flocks infected and number of environmental samples positive for *S. enteritidis* in the early part of PEQAP (February 1994) and over 5 years later (April 1999). Similarly, these reductions are supported in the public health statistics (Table 1) which show between 43.5% and 50.0% decrease in human *S. enteritidis* isolation rates from four States in the nine year period from 1989 to 1997. A combined overall human *S. enteritidis* isolation rate per 100,000 population of 49.4% was observed in the mid-Atlantic States where Pennsylvania is the chief supplier of shell eggs. These dramatic reductions are significant considering the association between human food borne *S. enteritidis* and grade A shell eggs (6).

PEQAP is a HACCP type program incorporating documented risk reduction measures. These include placement of *S. enteritidis* clean chicks, intensive rodent control with quantitative measurements of rodent populations through Rodent Indexing, cleaning and disinfection between flocks, basic sanitation practices and refrigeration of eggs at all stages of production, storage, and transportation (1,4,5). Pennsylvania enacted mandatory refrigeration legislation for commercial egg producers from farm to table in 1991. Comprehensive environmental monitoring of pullet and layer houses with testing of eggs and diversion of positive eggs for pasteurization or hard cooking is required. Producers enroll voluntarily, but over time Pennsylvania commercial egg producers increasingly are required to participate in PEQAP as a condition to sell eggs. Egg processors, food commodity brokers, insurance companies, and integrated commercial companies are increasingly demanding participation. With enrollment, individual

farmers receive education about *Salmonella enteritidis* and then make a personal commitment to achieve the higher management and risk reduction standards of PEQAP.

The structure of PEQAP is unique; featuring an oversight group consisting of: the Pennsylvania Department of Agriculture and the Pennsylvania Department of Health scientists and officials, representatives from two universities, and poultry members each from hatchery, grow-out, layer, and further processing segments of the industry. Each of these stakeholders have clear interests in specific portions of the outcome - to minimize *Salmonella enteritidis* contamination of shell eggs.