Delinquency Dynamics

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Abstract Crime has been an important issue for many decades. Most recently, juvenile crime has increased to the point that it could be considered a social epidemic, especially among the lower social economic classes. Due to the obvious correlation between adult and juvenile crime, we focus our efforts on the latter. In this study, we try to explain the dynamics of crime among poor adolescents for the immediate future. We find that an increase in delinquency prevention leads to a reduction in delinquent activity.

I. Introduction

Recent studies have shown that juvenile crime has increased rapidly in the last decade. This dilemma could be explained by an increase in the population due to the large number of offspring by the baby-boomer generation, and a lower family income (Elikann, 2). In other words, children that come from larger, economically disadvantaged families are more susceptible to committing crimes than any other children. In fact, youth crime arrests have increased from 31.74 to 51.19 million people in the last nine years (Vital). The nature of this sociological problem is such that it is possible to treat it as an epidemic. Delinquent behavior among teenagers is mainly learned from peers. Juveniles are more likely to commit crimes while they are in a group rather than by themselves. Interaction between a delinquent juvenile and a nondelinquent juvenile strongly promotes criminal behavior. To understand the dynamics of criminal behavior we have approached the problem of crime among juveniles as we would in epidemiology and developed a model.

The modeling problem is inherently complicated, as any other study that involves human dynamics. The main difficulty liest in selecting the most important factors. Some risk factors which are known to contribute to delinquency are "alcoholism, drug use, or mental health among parents; abuse, neglect, and inadequate or inconsistent parenting; criminogenic neighborhoods; problem in school; inadequate bonding with prosocial community institutions; involvement with delinquent peers; and poverty" (Greenwood, p. 97). Through our topic investigations, we conjectured that the youth program is the most important factor in reducing criminal activity among juveniles in detention facilities; and it can be controlled by both the government and the community.

This paper is divided into six sections. Section II describes the model and defines the parameters. Sections III and IV provide an analysis of the Basic Reproductive Number and equilibria. Section V describes our assumptions and graphical results. Finally, Section VI summarizes our conclusions and presents future research.

II. The SDA Model

Let S, D and A represent the total susceptible, delinquent and arrested juvenile populations, respectively. The system of equations is as follows:

$$
\begin{aligned}
S' &= \Lambda - \beta DS/(D+S) + \alpha D + (1-q)\delta A - \mu S \\
D' &= \beta DS/(D+S) - \Delta D + q\delta A \\
A' &= \gamma D - \kappa A \qquad (*) \\
N' &= S' + D' + A'
\end{aligned}
$$

where

$$
\begin{aligned}
\Delta &= \gamma + \alpha + \omega + \mu \\
\kappa &= \delta + \omega' + \mu.
\end{aligned}
$$

The total population N is divided into two groups, the active population and the inactive population. The active population is the sum of susceptible and delinquent juveniles. The inactive population are those juveniles who have been arrested and are isolated from the active group. Th susceptible juveniles become active among the delinquent juveniles through a contact rate of β. Delinquent juveniles are arrested at a rate of γ juveniles per unit time. Arrested juveniles return to the active population at a rate of δ individuals per unit time. A death rate of ω and ω' are considered for delinquent and arrested juveniles, respectively. The parameter $1/\mu$ is the average length of time possible in the juvenile years. The number of juveniles in after-school programs per unit time is represented by α. The constant recruitment rate into the susceptible class is Λ.

III. Basic Reproductive Number

The Basic Reproductive Number is the average number of susceptible juveniles that can be infected (pressured toward delinquency) when one delinquent juvenile is introduced into a susceptible population. Thus, let us assume that the delinquent and arrested population is zero, leaving the total population of susceptible juveniles at Λ/μ. Setting D' and A' equal to zero, we arrive at the following system:

$$
F(D,A) = \begin{bmatrix}
\frac{-\beta\cdot(D^*)^2}{(D^*+S^*)^2} - \mu & \frac{-\beta\cdot(D^*)^2}{(D^*+S^*)^2} - \alpha & (1-q)\delta \\
\frac{\beta\cdot(D^*)^2}{D^*+S^*)^2} & \frac{-\beta\cdot(D^*)^2}{(D^*+S^*)^2} - \Delta & \delta q \\
0 & \gamma & \kappa
\end{bmatrix}.
$$

Computing the Jacobian Matrix of F(D,A) and evaluating it at F(0,0), we have

$$
F(0,0) = \begin{bmatrix}
-\mu & -\beta+\alpha & (1-q)\cdot\delta \\
0 & \beta - \Delta & \delta q \\
0 & \gamma & -\kappa
\end{bmatrix}.
$$

The dominant eigenvalue of this Jacobian system will result in the Basic Reproductive Number

$$R_0 = \frac{1}{2}\left[\beta/\Delta + \sqrt{(\beta/\Delta)^2 + 4\gamma\delta/\kappa\Delta}\right].$$

The computation of the Basic Reproductive Number results in the stability analysis for the crime-free equilibrium. The crime-free equilibrium point, $(\Delta/\mu, 0, 0)$, is stable if and only if $R_0 < 1$. This condition occurs when $\beta < \Delta$. This is because the Jacobian of the system (*) evaluated at the crime-free equilibrium has the trace, $-\mu + (\beta - \Delta) + (-\kappa)$, which must be negative, thus $\beta < \Delta$.

IV. Endemic Equilibrium

Setting the system (*) equal to zero, we calculated the following endemic equilibrium:

$$\begin{aligned} S^* &= \frac{\kappa\Lambda(\delta\gamma q - \Delta\kappa)}{\phi}, \\ D^* &= \frac{\kappa\Lambda(\Lambda\kappa - \delta\gamma q - \beta\delta)}{\phi}, \\ A^* &= \frac{\gamma\Lambda(\Lambda\kappa - \delta\gamma q - \beta\delta)}{\phi}. \end{aligned}$$

where $\phi = \kappa^2\left[\beta(\alpha - \Delta) + \Delta(\alpha + \Delta - \mu)\right] + \kappa\left[\delta\gamma q(\alpha + \Delta - \mu) + \delta\gamma(\beta - \Delta)\right] + \delta^2\gamma^2 q$. The equilibrium (S^*, D^*, A^*) exists when $\beta > \Delta - \delta\gamma q/\kappa > 0$. This condition results from solving for the equilibrium, for we arrive at the expression:

$$S\beta = (D + S)(\Delta - \delta\gamma q/\kappa).$$

We also show that $\beta > \Delta$, thus the endemic point exists when $R_0 > 1$. With the Routh-Hurwitz criteria, we have shown that $W_i > 0$ for $i = 1, 2$ and 3. We need to show that $W_2 W_3 > W_1$. We conjecture that a stable endemic equilibrium exists when $R_0 > 1$.

V. Assumptions

We assume the following:

- We only consider violent crimes among juveniles. We define violent crime as murder, assault, rape, and homicide.

- We assume that participating in after school activities prevents and takes adolescents out of the life of crime. (α)
- There exists a constant number of youth per time unit (six months) that become juveniles.
- We assume adolescence is six years, ages 12-17; at age 18, the individual enters adulthood.
- The average life is four years as a juvenile delinquent before dying due to violent crime.
- The probability of dying in jail is very small if, on average, a delinquent spends one month per time unit arrested in prison.
- A large amount of information we found pertained to adolescents in poverty, so our model inherently assumes that the teenagers in the system are in the lower economic class.
- We assume a death rate due to violent crime for the susceptible group is 0.

The data acquired for 1992 was used to approximate parameter values which will yield the changes in S, D and A until 1995. Our assumptions allow us to verify the validity of our model and predict what could happen in the near future (see Appendix ? for parameter values). Through MATHEMATICA and MATLAB we obtained deterministic and stochastic solutions. We fixed all the parameters, varied alpha for three values (α = 67, 137, 33.5), and graphed both the deterministic and stochastic solutions. We expect a reduction in the number of arrests as alpha is increased and an increase in the number of arrests as alpha is decreased.

Figure Set 1: The value when $\alpha = 67$ was obtained from the validity of the model. This deterministic graph shows the increase in delinquent population, a decrease in the susceptible and arrested population. The system begins to stabilize after the first three weeks. In 1995, the arrest rate we obtained coincided with the actual rate of 1995.

Figure Set 2: The value of alpha was not changed. The deterministic graph shows a steady decrease in all three populations after the fri
irst week and a half. The stochastic stimulation resulted in the drastic reduction of 9.6 million susceptible juveniles to an average of 90.3 thousand juveniles (deviation = 30 thousand). The delinquent population increased

from 6.8 million to an average 13.74 million (deviation = 129 thousand). The arrests increase from 5.15 million to 7.01 million (deviation = 100.4 thousand).

Figure Set 3: The value of alpha was decreased by half, thus $\alpha = 44.5$. The deterministic graph shows a drastic increase in the delinquent population and a sudden increase in arrests. The susceptible individuals appear to decrease at a very fast rate. The stochastic simulation resulted in the drastic reduction of 9.6 million susceptible juveniles to an average of 45 thousand juveniles (deviation = 21.4 thousand). The delinquent population increased from 6.8 million to an average 13.79 million (deviation = 120.5 thousand). The arrests increased from 5.15 million to an average of 7.02 million (deviation = 103.5 thousand).

Figure Set 4: The value of alpha was doubled to $\alpha = 134$. The deterministic graph shows stabilization after six months. The stochastic simulation resulted in the drastic reduction of 9.6 million susceptible juveniles to an average of 183 thousand juveniles (deviation = 44.9 thousand). The delinquent population increased from 6.8 million to an average 13.65 million (deviation = 129.8 thousand). The arrests increased from 5.15 million to an average of 7.01 million (deviation = 104.6 thousand).

VI. Conclusions

Deterministicially, the results were obvious that as we increased the value of alpha, the arrests decreased to extinction or to a much lower proportion of the total population. We also noticed that there were times for very large values of gamma (the arrest rate); the system would oscillate then stabilize. We felt that this was sociologically insignificant since the time it took to oscillate was over 30 years. By that time, the arrest rates change and the factors involved differ. Surprisingly, the stochastic model did not change as alpha varied. One possible reason for this result lies in the randomness of the probabilities. The fact that we are considering a constant recruitment rate rather than a recruitment rate which depends on the total population of the system complicates the simulations. We remain convinced that through a deterministic method, one can justify and support the fact that youth programs can lower the delinquent and arrest populations considerably. "According to a recent American Psychological Association study, 94% of violent-crime fighting funds is spent not on prevention, but on punishment" (Elikann, cover). The effort and finance it takes to care for juveniles in delinquent facilities can be maximized through youth programs.

VII. Future Study

For future research, we could utilize two new factors: one measuring the poverty level and its effect on the increase in delinquents; and another representing a density dependence on the arrest rate. The first factor will help us measure the existence of a possible correlation between poverty and delinquency. As a result of density dependence on facilities, we would expect drastic changes in the dynamics of the system. Another suggestion for further research is to apply the model to individual states and compare the results. This can help us determine the generalility of the model and its limitations under certain conditions. For both studies described previously, we can introduce class structure or age structure. This will require the modification of the model into a system of partial differential equations.

References

Bronfenbrenner, Urie, Peter McClelland, Elaine Wethington, Phyllis Moen, and Stephen J. Ceci. *The State of Americans.* The Free Press, 1996.

Chadwick, Bruce and Time Heaton, eds. Oryx Press, 1996.

Decker, Scott H. and Barrik Van Winkle. *Life in the Gang: Family, Friends, and Violence.* Cambridge University Press, 1996.

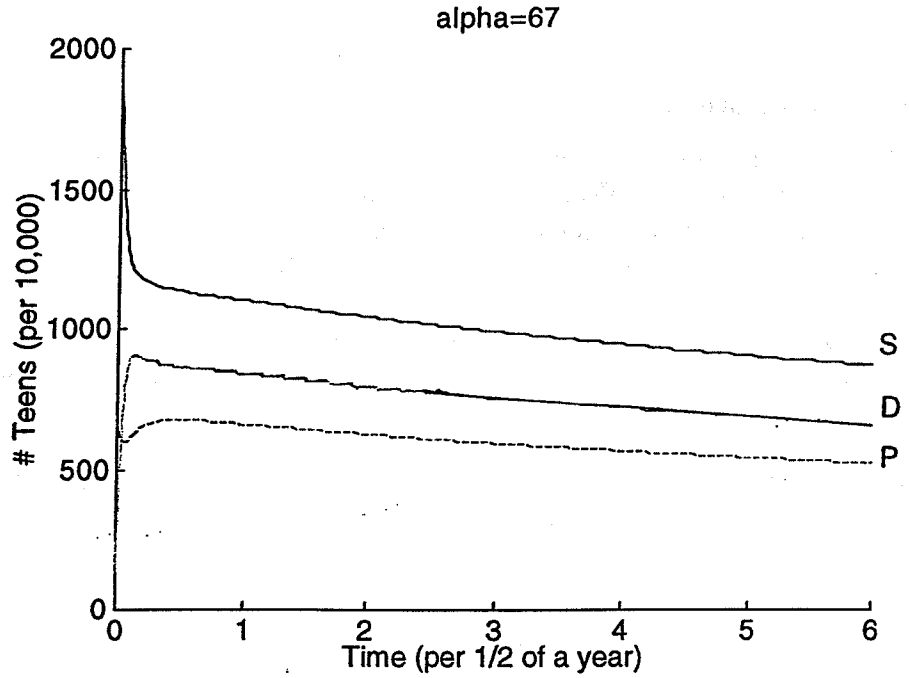
Elikann, Peter T. *The Tough-On-Crime Myth: Real Solutions to Cut Crime.* Insight Books, 1996.

Hawkins, J. David, eds. *Delinquency and Crime: Current Theories.* Cambridge University Press, 1996.

U.S. Bureau of the Census. *Statistical Abstract of the United States, 1992.* 112th Edition, Washington, D.C., 1992.

Vital U.S. Statistics and Facts. World Wide Web page: http://www.intantech.com/users/1260/index.htm#tenvio.

Wilson, James Q. and Joan Petersilia, eds. *Crime.* ICS Press, 1995. (Peter W. Greenwood)


alpha=67
2000
1500
1000
500
0
Teens (per 10,000)
S
D
P
0
1
2
3
4
5
6
Time (per 1/2 of a year)

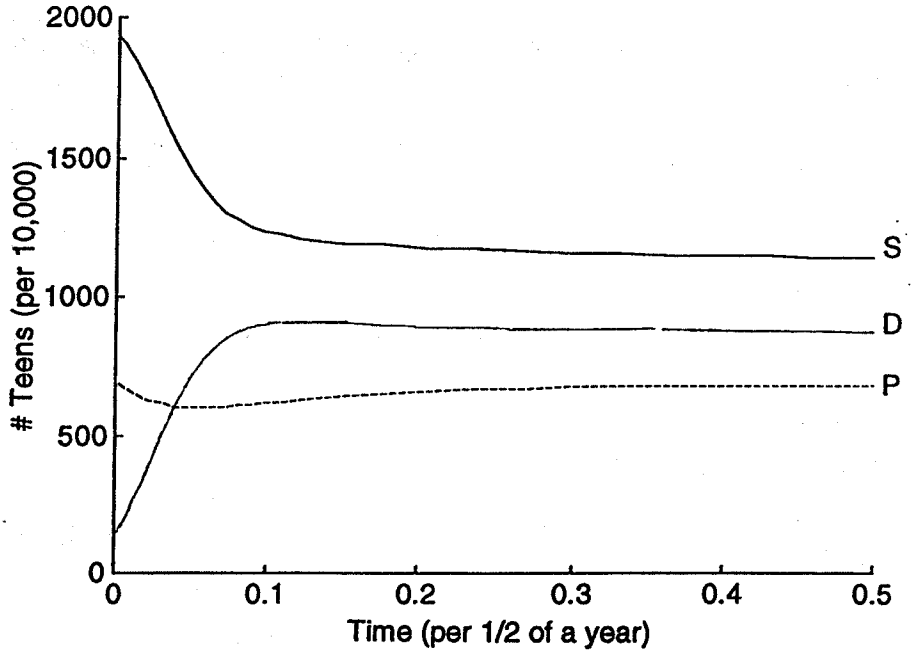
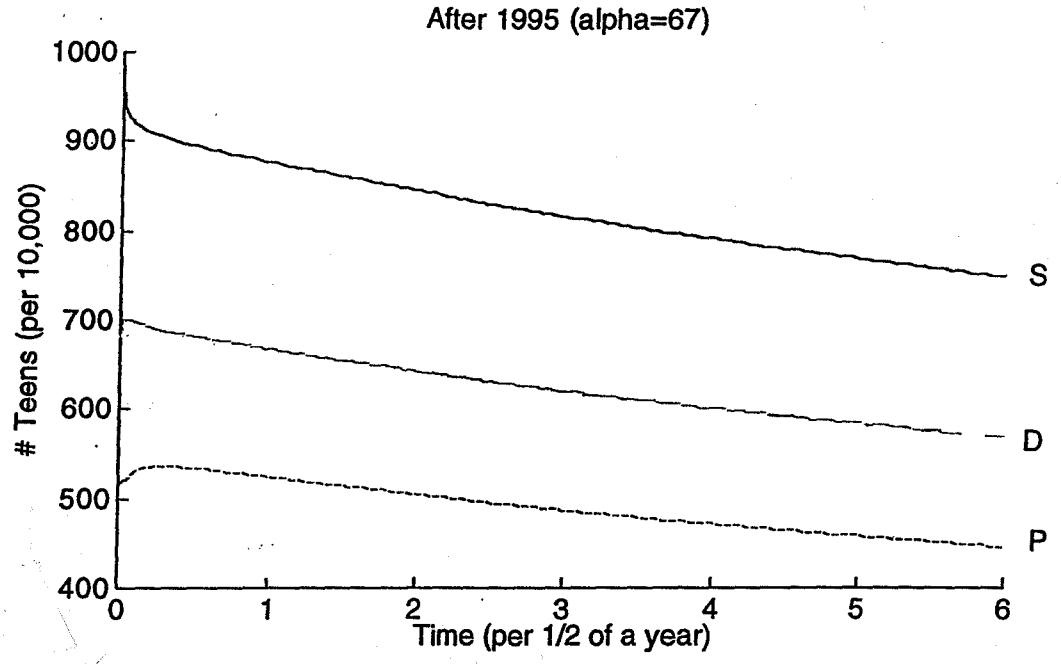

2000
1500
1000
500
0
Teens (per 10,000)
S
D
P
0
0.1
0.2
0.3
0.4
0.5
Time (per 1/2 of a year)

Figure set 1.


After 1995 (alpha=67)
1000
900
800
700
600
500
400
Teens (per 10,000)
0
1
2
3
4
5
6
Time (per 1/2 of a year)
S
D
P

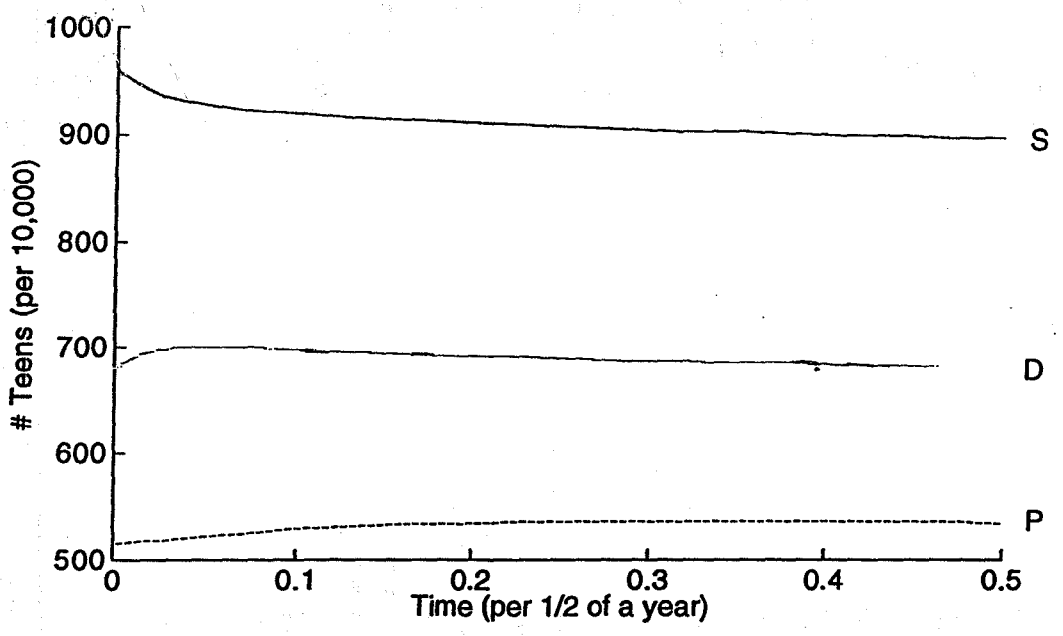
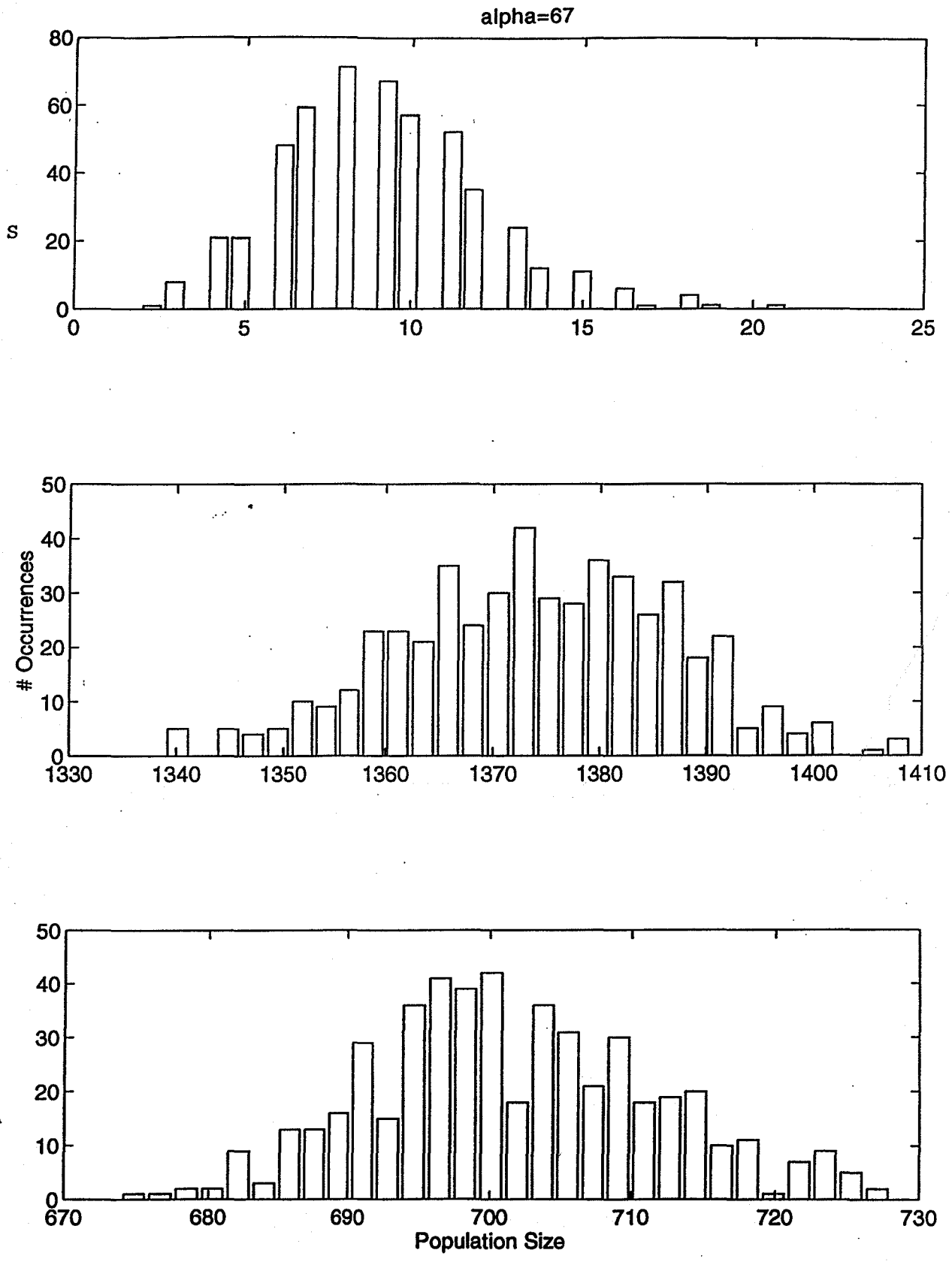

1000
900
800
700
600
500
Teens (per 10,000)
0
0.1
0.2
0.3
0.4
0.5
Time (per 1/2 of a year)
S
D
P

Figure set 2.



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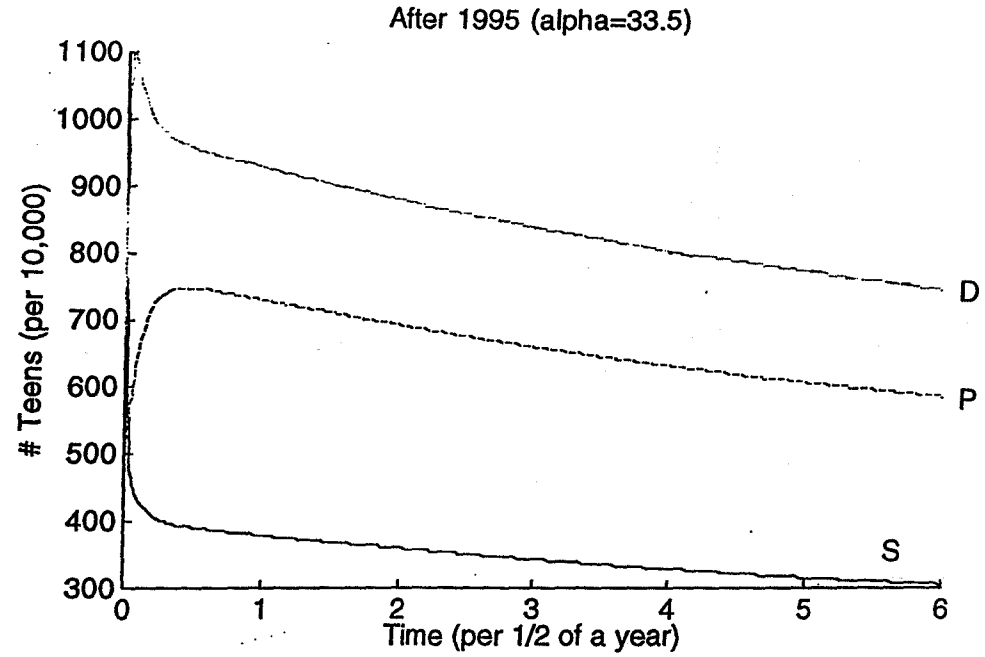
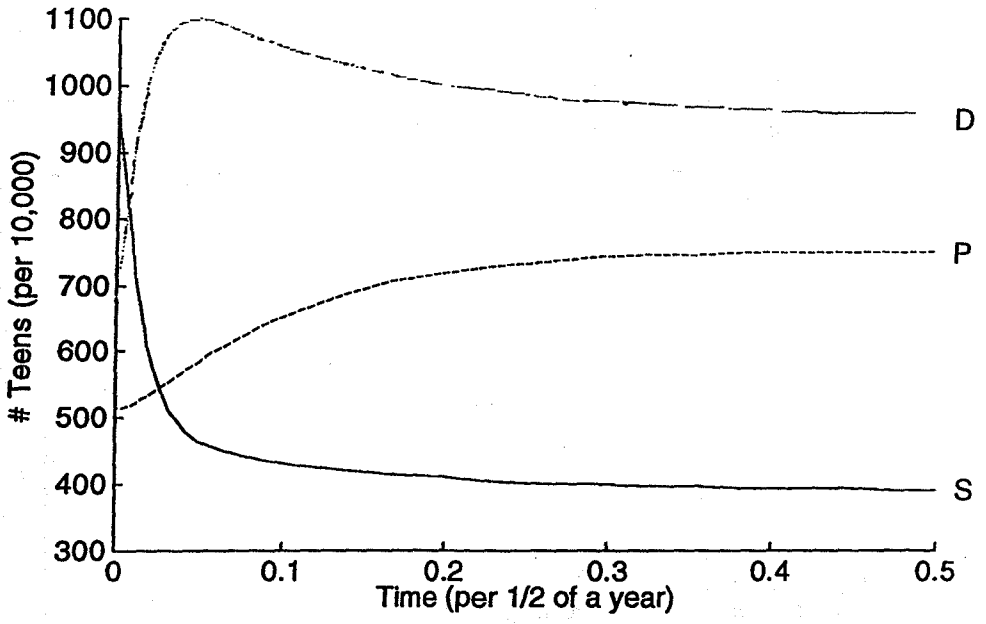

After 1995 (alpha=33.5)
Teens (per 10,000)
1100
1000
900
800
700
600
500
400
300
0
1
2
3
4
5
6
Time (per 1/2 of a year)
D
P
S


Teens (per 10,000)
1100
1000
900
800
700
600
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0.3
0.4
0.5
Time (per 1/2 of a year)
D
P
S

Figure set 3

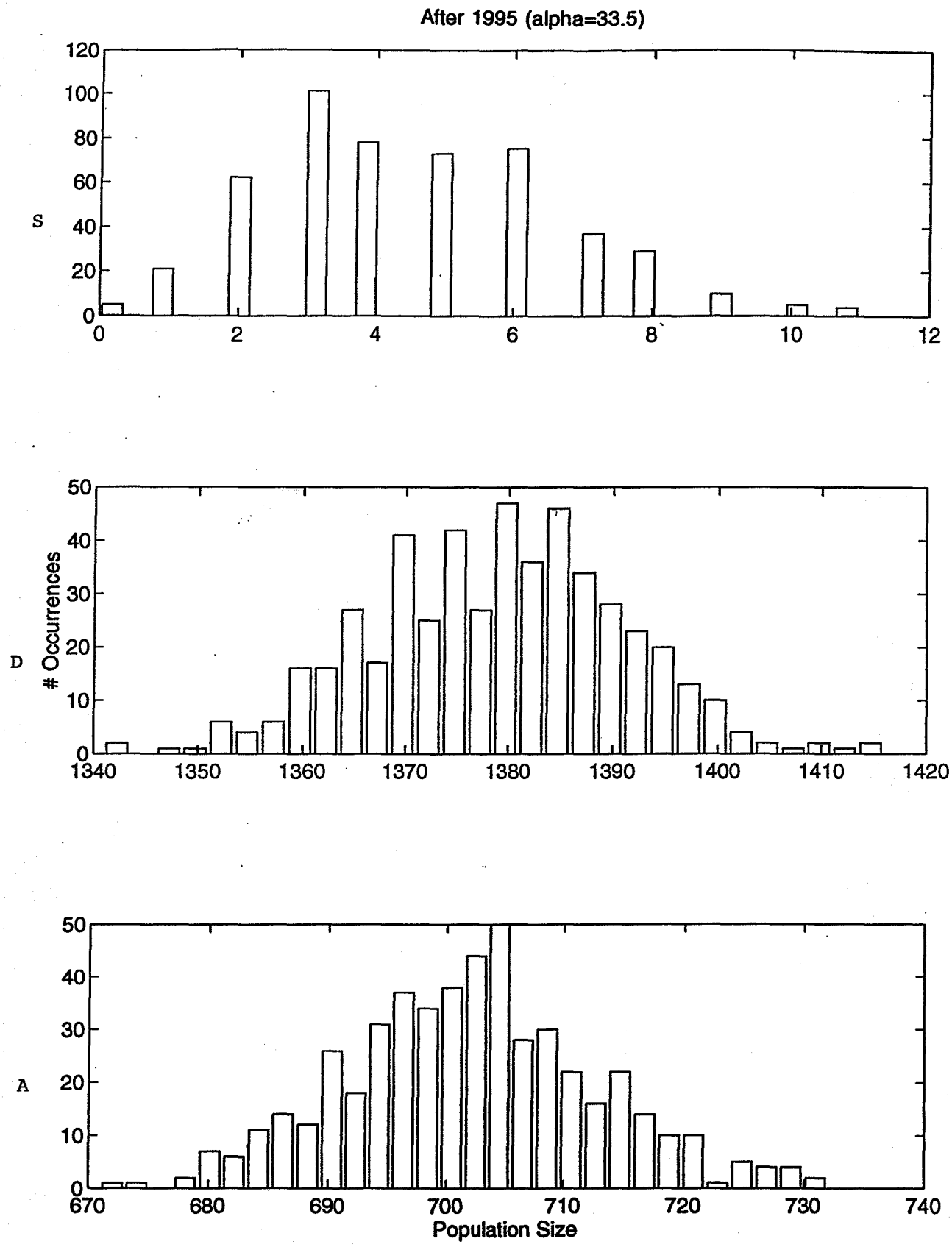
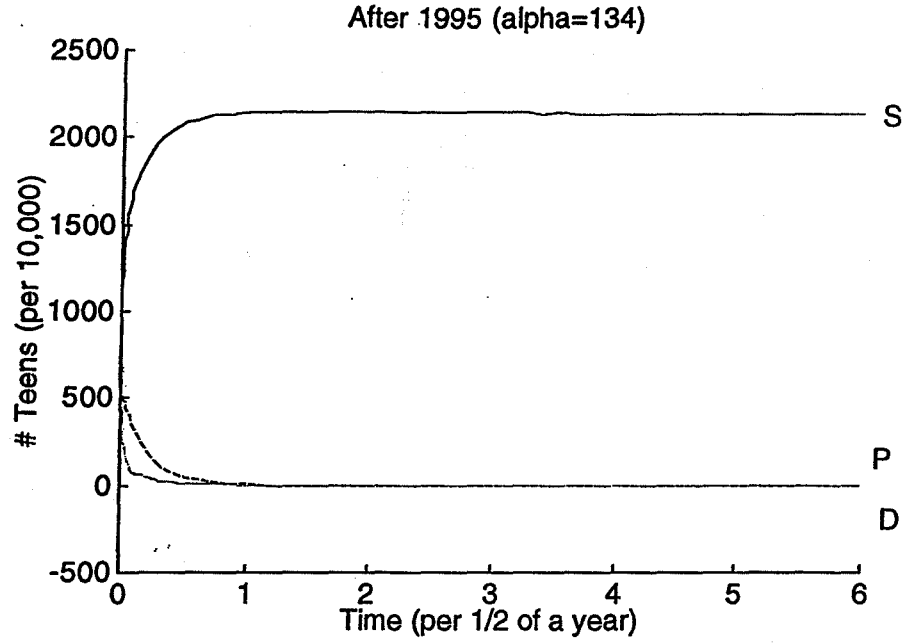


Figure set 3 cont'd


After 1995 (alpha=134)
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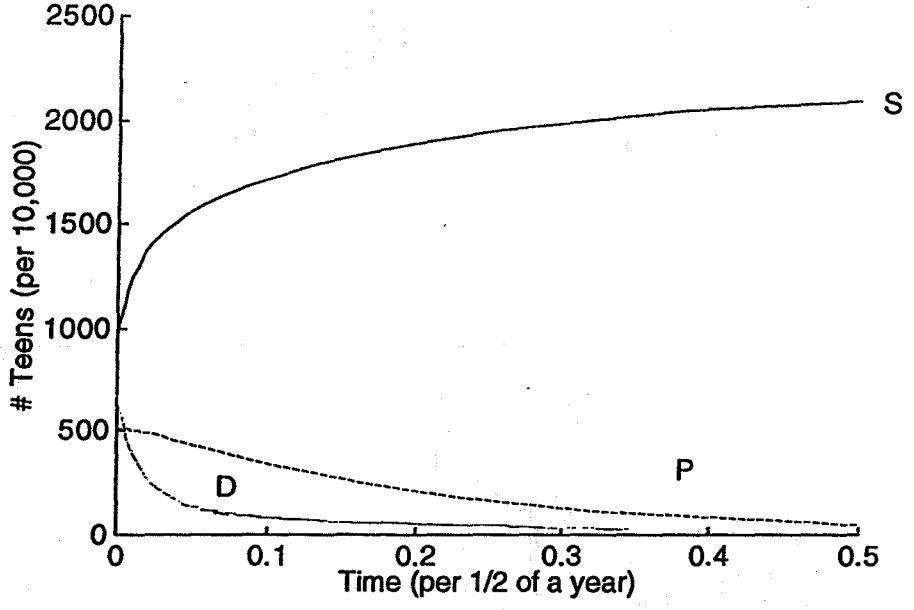
2000
1500
1000
500
0
-500
Teens (per 10,000)
S
P
D
0
1
2
3
4
5
6
Time (per 1/2 of a year)


2500
2000
1500
1000
500
0
Teens (per 10,000)
S
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0
0.1
0.2
0.3
0.4
0.5
Time (per 1/2 of a year)

Figure set 4

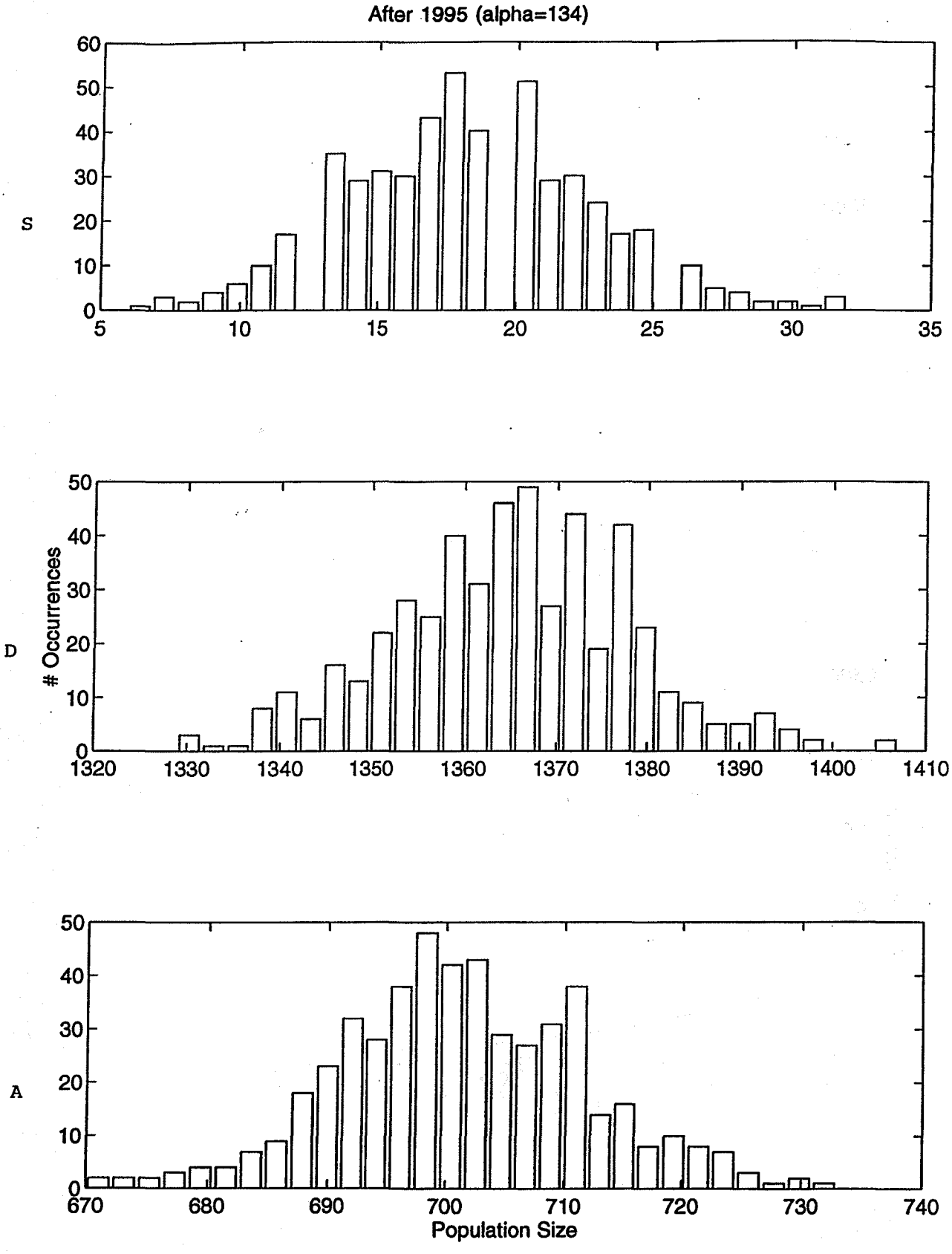

Figure set 4 cont'd