Population Simulator Program

Pop15 is a program that simulates the evolution of a human population over time. It is intended to illustrate some principles of population growth and decline in a vivid and dynamic way. You can play the role of king or czar and control population in the way that you think best. The program will show the consequences of your decisions as time goes on. You can even reverse time and change your decisions if you don't like the way they turned out.

You may be surprised to find that population dynamics are not as simple as they might appear. When age distribution is taken into account, some strange and surprising things can happen. After working with this program, you will probably know more about population dynamics than 999 people out of a thousand. This program is based numbers from the Statistical Abstract of the United States, 1989.

This program is shareware; it is copyrighted, but you may try it out for free and you may give copies to anyone, provided that you keep the program and the instructions together. If you find the program worthwhile, you are requested to send $5.00 to the author.

To start the program running, double click on the Pop15 icon, just as you would for most Macintosh application programs. You can control just about everything with the mouse. It is suggested that you run the program while reading the story below.

I. A Space Colony

The program contains population distributions for several different countries. When the program first starts running, it uses the population for a fictional space colony. This population is included to clearly illustrate some interesting features of population dynamics. The science fiction story below explains what is happening.

The Story

An expedition is sent a great distance from Earth in a spaceship to colonize a newly discovered planet. Life will be hard during the first years as the colony is clearing land, putting up buildings and getting established. Therefore the population of settlers includes no one over 40. However, children are included to provide the basis for the next generation. The colony is expected to be self-supporting and not require any additional supplies or settlers from Earth. According to the master plan, the colony is to keep a “stable” population during the early years, and then begin population growth after a few decades when life is easier and the burden of supporting many children is easier.

Imagine that you are population advisor for the colony. Your job is to keep track of population trends and advise the governor of the colony about adjustments needed to follow the master plan. The great ship lands on the planet in the year 2000. The original population has 1000 people in each age bracket or cohort; there are 1000 one year olds, 1000 two year olds, 1000 three year olds, and so on, up to the age of 40.

The term "cohort" is used by demographers to mean all the people born in the same year. All the individuals in a cohort have the same age (give or take a few months) which increases every year. For example, the people in the cohort of 1970 will all be 10 years old in 1980 and 20 years old in 1990.

Figure 1 shows the first screen that you see after starting the program: a graph of the original colony population, with one dot for each cohort. The horizontal scale gives the present age of each cohort; the vertical scale indicates the number of people in each cohort, in units of 100; thus 10.00 on the scale means 1000 people. The dots that represent each cohort form a perfectly straight line since there are 1000 persons in each cohort.

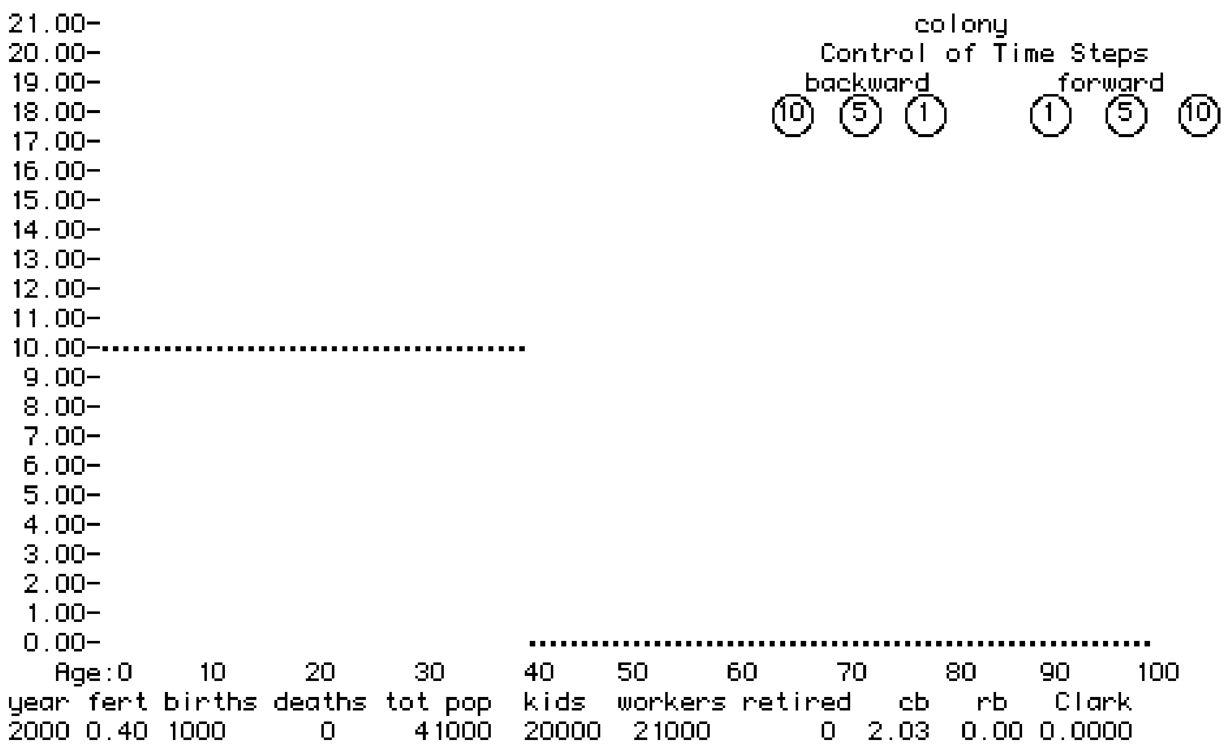

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Figure 1 above

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At the bottom of the screen are some numbers. 2000 is the current year. There were 1000 births, but no deaths during the year 2000. The total population is 41,000 of which 20,000 are kids (children) and 21,000 are workers. We assume that everyone from age 20 to age 65 is a worker. We will discuss the other numbers later.

To see what happens to the colony population during the first year on the new planet, click the mouse once on the “forward 1” circle near the upper right corner of the screen. You may also select **+1** from the **Step** menu. Both of these commands do the same thing, advancing the simulation by one year. After the screen regenerates, you should see a slightly different picture. The year is now 2001, and there have been some births and deaths.

Whenever the program advances, it computes the births and deaths for one year and makes each cohort one year older. The number of births depends on the number of people in the childbearing years (mainly age 15 to 40). The program “knows” the relative number of babies born to women at each age. We use 1987 US statistics for these numbers. The number of babies born also depends on the fertility rate. This rate may be changed, but is initially set at 0.4 for the space colony. This means that the average family will have 0.4 children, a rather low rate.

The program also “knows” the death rate for each age, again using current US statistics. For example, only 19 people out of 100,000 will die at age 10, but 2962 people will die out of 100,000 at age 70.

The key point to remember is that the number of births and deaths for each year in this simulation depend not on the total population, but on the age distribution of the population, just as it does in real life.

In the case of the new space colony, it is obvious that about 1000 births are needed each year to maintain the continuity of the population, but life is difficult at the start of a new colony so during the first year only 198 babies are born and 50 people die.

You advise the governor that steps should be taken to increase fertility. He replies, “198 babies were born and 50 people died, is that correct?”

“Yes, but..”

“Then simple arithmetic tells us that our population has increased by 148 people”

“Yes, but..”

“According to the master plan we should maintain a *stable* population at this time. Yet you admit we are growing. If anything we should try to reduce fertility.”

“But Governor, our death rate is artificially low because we have no older people. Eventually the death rate will be 1000 per year, thus anything less than 1000 births per year will eventually result in a population decline.”

The governor replies, “Look, is the population growing or is it not?”

“It is right now, but that won’t last. Governor, the important thing to watch is the fertility rate, the average number of children per family. It is perfectly clear that two parents must have two children if the population is going to be stable. Actually the magic number is 2.1, since a few children die before they reach adulthood. If the fertility rate stays below 2.1, the population will eventually decline. Our fertility rate is now only 0.4. We must increase it to at least 2.1.”

“I do not understand what you are talking about. Our population is growing now. That is the important thing. That I understand. No change in the fertility rate is needed.” (It is clear that the governor is not very bright. Some say that he got his position through nepotism.)

Notice the number of 0.40 under “fert” at the bottom of the screen. That is the current fertility of the population. Now click four times on the **+1** button, and once on the **+5**, so that we advance to the year 2010. You will notice that there is a delay after you click on **+5** because the computer takes a few seconds to calculate five years of simulation.

In the year 2010, the population chart looks like figure 2:

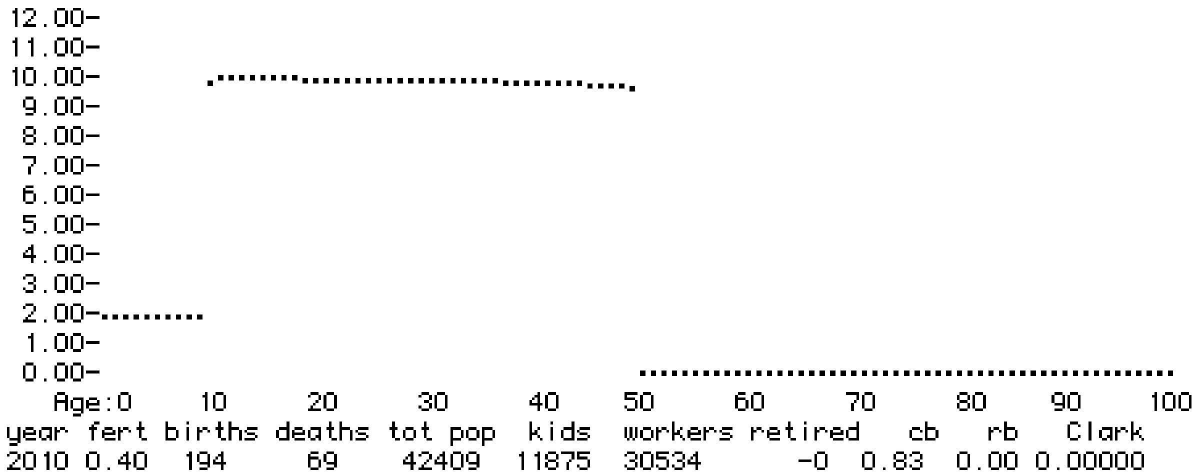


Figure 2 here ****************

Notice that the rectangle that represents the original population of the colony has shifted ten years to the right; this group is getting older. Also, the top of the rectangle is no longer flat. It slopes to right because the death rate is greater at older ages.

The smaller rectangle from age 0 to 9 are the children born since landing on the new planet. Let us call this group “the second generation.”

You show this chart to the governor. After studying it he says “Aha, I see that there are still more births than deaths. Our population is still growing.”

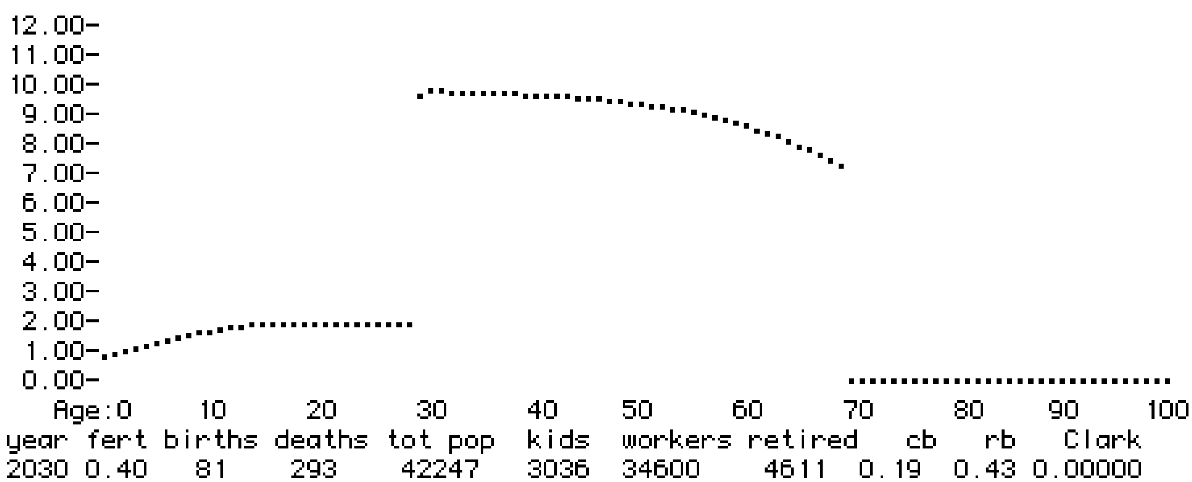
You reply, “But Governor, there is now a deep valley, a hole, in our population chart from age zero to 9. In 20 years those children, the second generation, will be in their 20s; the age bracket in which most women have their children. The number of births each year will fall drastically then. In thirty years those people will be in their 30s, our prime workers. It will be very difficult to maintain production with this hole in our age structure. “

“Maybe so and maybe not” replies the governor. “I don’t understand all this technical mumbo-jumbo. You have predicted population problems every year since we landed, but somehow these problems never happen. They are still in the future, you say. If and when these problems that you are so worried about actually do begin, then I will take action to solve them, that’s fair enough is it not?”

“But governor, it will be too late then.”

“Maybe so and maybe not.” mumbles the governor.

Now click on the **+10** button. There is a few seconds delay as the simulation advances 10 years. If you look closely at the screen you can see the changes rippling across the population graph, as the computer calculates a new number for each age every year. Click again to reach the year 2030. After 30 years at a fertility rate of 0.4, the chart looks like figure3.



******* Figure 3 here

Notice the nearly flat line in the second generation, from about age 10 to 29. This is because during the first 20 years of the colony, the number of babies born was nearly constant, about 200 per year. This happened because the fertility rate was constant, and the number of people in the child-bearing years was nearly constant. Then, as the first generation moved out of the child-bearing years, being replaced by the much smaller second generation, the number of births began to fall, even though the fertility remained constant. This explains the slope of the line from age 0 to 10. Also, the number of deaths has increased greatly because the original population is getting older.

The governor studies the chart and remarks, “We had 81 births this year and 293 deaths, that is a net loss of 212. So the decline you have been predicting has finally happened. But it is small and has not hurt us much. Our total population is 42,247, still larger than when we landed. But I think we ought to act early, we ought to nip this thing in the bud. So I will take steps to increase the fertility rate to 2.1 as you wanted.”

“Thank you governor, but we have waited so long that we now need a much larger fertility rate, at least 4.2, in order to survive.”

“Now just a minute. You said, that if the fertility rate were 2.1 the population would eventually stabilize; two parents must have two children. Those were your exact words, were they not?”

“True, governor, at a fertility rate is 2.1 the total population would stabilize in the long run, but a lot can happen in the short run, before things settle down. There are now relatively few people in the child-bearing years. At a fertility of 2.1, our total population would decline for many years and our colony could not function with a small population. We need a rate of 4.2 to have a fighting chance for survival.”

“Maybe so and maybe not. A fertility rate of 4.2 sounds unreasonable. But, I do see your point. We have too few people in the 20 to 30 age bracket. I want you to study the problem and work out a plan to increase the population in that age bracket, during the next 10 years.”

“But...”

“No buts. That is an order. Get busy.”

Later you describe your interview with the governor to your friend, Tom. He is astonished. “The governor want you to work out a plan to increase the number of 20 year olds within 10 years? I can’t believe it. No one could be that stupid. Even a child knows that it takes 20 years to make a twenty year old person.”

At last, the governor does take action. By publicity, tax credits, and other incentives the fertility rate is brought up to 2.2, slightly above the magic number 2.1. (Select **2.2** from the **Fertility** menu and advance one year at a time to see what happens.) The governor is very proud of himself when he sees total population slowly climbing, but the number of deaths continues to increase as the population ages, and then the number of births falls off. Four years later, the governor is astonished when total population begins to decline once again. Use the mouse to advance to 2050. After 20 years at a fertility rate of 2.2, the chart looks like figure 4.

**** Figure 4 here

Although the total population has not fallen very far, the number of workers has dropped drastically to 17,998. Also the number of retired people is 13,116 which is quite high relative to the number of workers. Note the number called rb at the bottom of the chart. This stands for “retired burden.” It is the number of retired people that each worker must support, but the ratio has been normalized. In other words, rb = 1.00 is the level that we consider normal. If rb is greater than one then the burden is greater than normal. In this case, rb = 2.40 which means that the retire burden is almost two and one half times greater than normal. (We will explain later in more detail.)

Even though things look grim, the governor is optimistic and decides to hold the fertility rate at 2.2. He reasons that 2.2 is above the replacement rate of 2.1, and therefore, the population is sure to start growing, someday. (click the **+10** button twice.) After 20 more years, the population chart looks like figure 5.

Figure 5 here *****

Total population is still falling. The Governor cannot understand this, since the fertility rate, 2.2, is above the replacement level, 2.1, and has been for *40 years*. The number of workers is now below 10,000, the estimated minimum needed to keep the colony alive. Also, rb (the retire burden) is 4.04 which means that each worker must support four times the normal number of retirees. As the colony teeters on the brink of extinction, the governor is displaced by a palace revolt.

The colony struggles for survival by raising the fertility rate to 4.4, increasing the retirement age, and taking the most extreme measures of frugality.

You can increase fertility by selecting **type in** from the **Fertility** menu. You may then type in 4.4 and hit the return key. (If you don't like to type, select **4.0** from the **Fertility** menu, and then select **Increase 0.1** four times.) Then advance the program by one or five year steps to see what happens.

Even with this high fertility, the total population continues to decline for 14 years. It is 20 years before the high fertility even begins to increase the number of workers, and it is 51 years, the year 2121, before the number of workers reaches the reasonably comfortable level of 20,000, and emergency measures can finally be ended.

Conclusions

The above story illustrates several points about population. The total population of a nation does not accurately describe the total picture. If one looks at the population distribution by age, one gets a much more clear picture. The growth of the total population is not the best measure of where a population is headed. Growth is births minus deaths. The number of deaths depends on the number of people born 70 to 80 years ago. Therefore, when we look at the present growth rate of a population, we are looking into the past. Fertility rate is probably the best measure of whether a population is growing or not.

Population Momentum

Most people assume, without really thinking about it, that the growth of total population responds immediately to any change in the fertility rate. They believe that the total population must increase in any year that fertility is above 2.1; likewise that total population must fall as soon as fertility drops below 2.1. But this is not correct.

When we think about controlling population, we must remember that population growth has a kind of momentum. When a population has been growing for a number of years, it acquires an age structure that makes growth easy; a relatively large number of people in the child-bearing years, and a relatively small number of older people. The population in our story above had this type of structure in the beginning. That is why it was able to grow for over twenty years, even through the fertility rate was a very low 0.4. The governor, looking only at total population growth, thought everything was fine; he was wrong. The advisor, looking at the fertility rate, knew that trouble was brewing; he was right.

The low fertility rate of the colony used up the positive momentum of the population and then built up a negative momentum. When the fertility rate of any population is too small (less that 2.1) for many years, the number of people in the childbearing years becomes relatively small, while the number of older people becomes relatively large. This causes negative population momentum; the fertility rate must be far above 2.1 to cause such a population to grow.

By 2070 the colony had such a large negative momentum that even a fertility rate of 4.4 could not make the population grow. (It finally began to grow after 14 years.) The momentum of population growth is a real effect, but few people understand it. You are now one of the few.

Archives

Hidden in the program is an “archive” that records important population statistics each year as the system moves forward. Use the **Plot** menu to select **Fertility**. This command plots a graph of the fertility over the years that the system has been simulating. As you recall we started with 0.4, then after 30 years, increased to 2.2, and finally, 40 years later, increased to 4.4. All of this history is shown on the screen.

There is not room on the screen for more than 100 years of data. If you again select **Fertility** from the **Plot** menu, you will see the second 100 years. Note that the fertility falls to zero towards the end of this period. That is because the program has not simulated those years; there is no history. The other **Plot** commands work the same way; select a command once and you get the first 100 years of history; select it twice in a row, and you get the second 100 years. Now you may look at the other statistics in the **Plot** menu.

The **List** menu works in the same way except that the statistics are displayed on the screen as a table of numbers rather than a graph. Select **Fertility** from the **List** menu.

When you first load a population, the archives begins recording at year one. As you advance forward, the archives record the new data for each year, but can hold only 200 years of data. If you move forward more than 200 years, the archives records the new data each year by writing over old data. You can advance forward 500 or 1000 years or as far as you like. The archives will always hold the most recent 200 years of data.

After you have finished using the **Plot** and **List** commands, select **Rescale** from the **Other** menu. This will put the population chart back on the screen.

Time-Travel

Now we discuss how to use the “time-travel” feature. Use the **-10** button to go back 10 years. The program simulates population changes in reverse and changes everything back the way it was 10 years ago, with one exception; the number of births and deaths are not correct. These numbers are calculated correctly only when the simulation steps forward. Click on **-1** and then on **+1**. The display will now be entirely correct. (You can also use the **Rescale** command to clean up after time travel.)

You are not allowed to change the fertility or the historical statistics when moving backwards in time. The program uses the fertility value recorded in the archives. This insures that, when you back up to a particular year, everything will be exactly as it was before. In this respect, it is just like time-traveling. But when you travel forward again, you can change fertility and thus create a different future.

Now use the mouse to go back to the year 2030 and change history. Increase the fertility to 4.4, which the stupid governor refused to do at that time. Then move forward and see what would have happened if the governor had been wiser.

Now go back to the beginning, the year 2000. You can do this by running the simulation backwards, or you can take the *secret shortcut*; select **Colony** from the **Data** menu. This command starts the space colony population at the beginning; the year 2000. Then advance to 2001, assassinate the governor and set the fertility where *you* think it ought to be.

Automatic Advance

Now select **Forward** from the **Speed** menu. This sets the time machine into forward gear. Then select **Medium** from the **Speed** menu. The program will now advance automatically. Each year will be on the screen just long enough for you to get a good look at it. Now you can lean back and see how things work out when you make the decisions instead of the mentally retarded governor.

As the simulation moves forward, you can change fertility just as before, but the mouse only works while the program is waiting (about half the time), not while it is computing the next year. When you are ready to stop, select **Single-step** from the **Speed** menu.

The Static Population

Now we will discuss the “static” population and the definition of *cb* and *rb,* child and retire burdens. If the fertility of a population is exactly at the replacement rate, 2.1, for a long period of time, that population will become stable or static. In this case, the total population is neither growing nor declining, and there is no change in the age structure. The number of people in each age group remains the same as time goes by. The static population has zero momentum;

if the fertility is set above or below the replacement rate, the total population will immediately begin to grow or decline.

We have selected the static population as a standard for measuring cb, the child burden, and rb, the retire burden. In the static population, 100 workers must support 31.3 retirees. This is the number that we define as normal; in this case rb = 1.00. If each 100 workers must support 15.6 retirees (half of normal), then rb = 0.50. If each 100 workers must support 62.6 retirees (double normal), then rb = 2.00. The program assumes that all workers retire at age 65. The child burden, cb, is computed in a similar way. In the static population each 100 workers must support 47 children and this is defined as normal; in this case cb = 1.00.

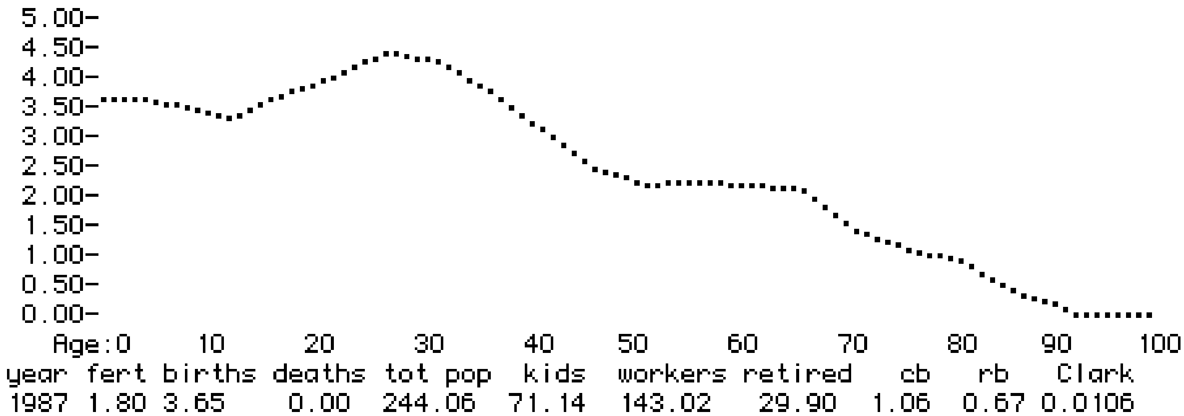
You can make a static population by setting fertility to 2.1 and letting it run for a few hundred years. There is normally a static population in the folder with Pop15. You can read it into the program by means of the **Open** command in the **File** menu, selecting the file “Static Pop.”

You can save the current status of the active population by use of the **Save** command in the **File** menu. Pop15 will ask you to give some name to the file.

II. The Population of the United States — 1987

Select **USA-87** from the **Data** menu. This will load in the population of the United States as it is right now. Well, almost now; 1987 is the most recent year for which data is available. This data is from the

Statistical Abstract of the United States, a publication of the Census Bureau. The screen should look like this:



The vertical scale is millions of people in each cohort. You can read the history of the United States in this population distribution. Note that the number of people in the older age groups, 70s and 80s, is relatively small. This is because the total population of the United States was much smaller 70 and 80 years ago when these people were born. There is a minor hill at about age 65; this is caused by high fertility during the prosperous “roaring 20s.” There is also a broad valley centered about age 50. This valley is the legacy of the great depression of the 1930s. You can see a hill in the population from about age 20 to age 40. These are the “baby boomers” born between 1946 and 1968. There is another valley from age 20 down to age 0. This called the “birth dearth” by some demographers. Fertility has been below the replacement level during the 1970s and 1980s.

Now click on **+1** to advance to 1988; this will compute the correct number of births and deaths. Because of your experience with the fictional space colony population, you will notice that the United States has the same problem as the colony; too few children are being born. The fertility rate is 1.8, well below the replacement rate of 2.1.

The total population is still growing because of the great positive momentum in the age structure built up by the baby boomers during 1946 to 1970.

Projection at 1.8 Fertility

The fertility in the USA has been about 1.8 since 1972. This means that we are using up our positive momentum. The birth dearth kids are now beginning to move into the child-bearing years. As they displace the baby boomers, the number of babies born each year will begin to decline, even if fertility remains constant. Run the program forward a few decades to see what will happen if the fertility remains at 1.8.

You will note a decrease in the number of births every single year, while the number of deaths increases every year. In the year 2014 deaths finally exceed births and the total population peaks at about 260 million and then begins to decline. Negative momentum is building up, so the decline becomes more and more rapid. By 2032 the total population is falling by one million per year.

Advance to the year 2100, and note that total population continues to fall. By 2100 the total US population is down to 169 million and still falling. You can now use the **List** command to look at population statistics between 1987 and 2100.

Total population is widely used, but is not a the best national indicator. The number of workers is a better measure of national strength, since they are the ones who produce goods and pay the taxes. The number of workers is increasing at first, but reaches a peak of 161.5 million in the year 2010. After that workers steadily decline.

The retire burden is now (in 1990) only 0.68, but it steadily increases, hitting a peak of 1.24 in 2036 when the baby boomers retire. It drops off a little and finally stabilizes at 1.22 in the year 2100. This suggests that social security payroll taxes will almost double. The increase in the retirement burden is perhaps the most serious problem in our future. The computer model understates rb for reasons that are discussed below in the section of “Accuracy of Computer Prediction.” The retire burden could easily be 30 to 50 percent greater than we have calculated. The social security taxes are now a serious load. Half of these taxes are paid by the employer, which means that they are actually higher than most people realize. These taxes will have to double, or more.

Clearly, the United States is heading for trouble, if the fertility rate does not increase. Now let us see if we can fix the problem.

Projection at 2.2 Fertility

Let us go back to 1990 and then increase the fertility rate to 2.2, just a hair above the replacement rate. The quick way to do this is to select **USA-87** from the **Data** menu, then advance three years, then increase the fertility rate. Next click on **+10** repeatedly until we reach the year 2100. The population events of 113 years are now recorded in the archives. You can look at them by using the **Plot** menu for the big picture, or the **List** menu to get specific numbers.

First let us look at the number of children. This number is falling prior to 1990, but then it begins a steady increase. This is interrupted by a minor dip of about half a million between 2010 and 2020, when the birth dearth kids are in their childbearing years.

The number of workers also increases steadily except for a dip of about 6 million between 2017 and 2041. Total population increases steadily, reaching 321 million by 2100. This is certainly a great improvement over a fertility rate of 1.8, but there is still one problem. The retire burden peaks at 1.10 in 2033, a 61 percent increase over the present rb. An improvement, but still a heavy load.

Projection at Higher Fertilities

Let us go back to 1990 and try a fertility rate of 3.0, and then 4.0. Results are summarized in the table below. The Clark number is a measure of "overpopulation" that we will explain later.

**** Randy: This is a table. Be sure to format appropriately.

Fertility	peak rb	final rb 2100	total pop 2100	Clark number
1.8	1.24	1.22	169 million	0.0073
2.2	1.10	0.94	321 million	0.0139
3.0	0.92	0.62	943 million	0.0410
4.0	0.78	0.41	2800 million	0.1217

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Our Big Problem

The modest increase in total population that the United States is now enjoying is a temporary thing. The number of babies born each year is too small, and has been too small for the past 20 years. Trouble is brewing because our positive momentum is being rapidly used up. Our window of opportunity is closing as the baby boomers move out of the child-bearing years. We need to increase our fertility rate as soon as possible. Most people are unaware that there is any problem because they focus on the increase in total population, and pay no attention to fertility, like the Governor in the space colony example.

Zero Population Growth

There are many people who feel that the danger of overpopulation is so great that we should do everything possible to reduce population growth. Some feel that the goal should be zero population growth. Let us see what would happen if we followed that plan.

Select **USA-87** from the **Data** menu, then advance three years to 1990. Now select **ZPG** from the **Other** menu. This engages an “automatic pilot” that adjusts the fertility each year so that the number of births is equal to the number of deaths. Therefore population growth is exactly zero, and the total population is exactly constant all the way to 2100 (or as long as you care to run the simulation).

The first thing we notice is a dramatic drop in the fertility rate from the present 1.8 down to 1.21. The fertility rate then immediately begins to increase. It reaches a peak of 2.79 in 2034, then it drops again to a low of 1.71 in 2076. Fertility begins to rise again; it is 2.22 in 2100 and still rising. Look at the fertility curve using the **Plot** menu and you will see that it resembles a roller coaster.

The retire burden still hits a peak in 2036 when the baby boomers retire, but now it is much higher, 1.35, higher than any of the plans listed above. The rb then drops to a low of 0.77 in 2080 and then starts up again. It reaches 0.98 in 2100 and is still rising.

If the United States were to seriously follow the ZPG plan, we would need a huge effort to drastically reduce fertility very quickly to 1.21, then we would immediately begin increasing fertility up to the moderately high peak of 2.79 (this is necessary to hold total population stable as the baby boomers deaths hit a peak). ZPG stabilizes total population but it destabilizes everything else; fertility, number of children, number of workers, and most important, the retire burden. It gives us a roller coaster ride. Our biggest demographic problem, the retirement burden, is made substantially worse by strictly following ZPG.

It is clear that the ZPG people are looking at the wrong measure, total population. Forcing total population to be stable causes a raft of other problems. Assuming that one wanted to stabilize population, it would make a great deal more sense to stabilize the fertility rate; this is much easier to do since there is no need for rapid reversals in the program of incentives, and it has the great virtue of tending to stabilize all the other important population statistics.

Those who advocate zero population growth seem to be unaware of population dynamics, and in this respect, are very much like the governor in the science fiction story in section II.

Accuracy of Computer Prediction

Is this program really an accurate prediction of what will happen in the US in the future? The fertility rate has been about 1.8 for the past 18 years. But it has changed in the past and could change in the future. No one knows how or when it will change. One should not think of this program as a prediction, but as a simulation of what will happen *if* fertility remains at 1.8 (or whatever level you may set).

Mathematically the program is accurate. It uses the fertility profile of the United States at this time. This profile indicates the relative number of babies born to women as a function of age. You can look at it by selecting **Fert-age** from the **Plot** or **List** menus. Any change in this profile that might happen in the future would have little effect on the results.

The program also uses the survival profile of the US at this time. This profile tells the proportion of deaths at each age. You can look at it by selecting **Survival** from the **Plot** or **List** menus. The death rate has been going steadily down. It is reasonable to expect that it will go down more in the future. Possible future changes in the death profile have not been simulated in the model. But such changes would probably have only a modest effect of the results of simulation. The effect would be to increase the numbers of people in the older age brackets.

The future rb or retire burden is probably understated by the program for several reasons. First, the program assumes that people retire at 65. Actually, the average age of retirement is a bit less than 65 now, and the trend is toward still earlier retirement. Second, the trend is toward people living longer. It is a reasonable bet that people will be living three to five years longer when the baby boomers retire. This is also not included in the program.

This program simulates only population changes due to births and deaths; This is what demographers call “natural increase.” The effects of people moving into or out of the country (immigration) are not included. The number of people entering the US illegally has been greatly exaggerated in the headlines. The actual number is estimated by Wattenberg at 0.435 million net gain per year (Wattenberg p 24), including both legal and illegal immigration and emigration (people moving out of the country). This number is small compared to the number births per year, presently about 3.5 million. If immigration were included, it would have a small but noticeable effect. Total population would begin to decline perhaps 8 to 10 years later than the time predicted, and the decline would be slower; about 0.6 million per year instead of 1.0 million per year. However the general conclusions would still be the same.

Changes in the fertility rate are difficult to predict, but demographic projections are highly accurate when the people involved have *already been born*. For example, the program predicts that a relatively large number of people will be retiring in the 2011 to 2035 period. These are the baby boomers who were born in the 1946 to 1970 period. This prediction is highly accurate because the baby boomers are already adults. This prediction has nothing to do with the uncertainty of future fertility; the program is only predicting that the baby boomers will get older. This is very close to a certainty.

What it Means to You

Real estate will be a less desirable investment. As the number of young people coming into the housing market falls, the price of houses and apartment buildings will increase less rapidly than in the past and may even fall. This trend should begin in the 1990s and will steadily get worse.

Retirement may also be a problem. It is almost a certainty that, in the next 40 years, there will be a smaller number of workers supporting an increasing number or retirees. The Government does not put Social Security tax money collected from a worker into the bank and then pay it out when that worker retires. Social Security is a hand-to-mouth operation. Social Security taxes, now 14 percent, will have to about double if benefits are to remain the same. It is highly doubtful if workers will accept a doubling of the taxes to the 30 percent range (in the worst case it could be 37 percent — Wattenberg p.70). Note that we are speaking only of social security taxes; this is on top of ordinary income tax. Since the number of workers will be falling, there will be pressures to increase the income tax as well. Perhaps the retirement age will be increased. Perhaps the benefits will be reduced. Something will have to give!

If you are now retired, you should face few problems, unless you live an unusually long time. But your children and grandchildren will have some difficulty. If you were born before 1946, then you may face some problems during the late part of your retirement. If you are a baby boomer, born between 1946 and 1970, then you will face the brunt of the problem. The last of the baby boomers, those born in the 1960s will face the greatest problem. You had best put some money in the bank and not count entirely on Social Security. The birth dearth kids, those born after 1970, will be asked to pay greatly increased social security taxes. The late baby boomers and the early birth dearth kids face the worst of both worlds. They will be asked to pay increased taxes before they retire, and then can expect lower benefits after they retire.

Wattenberg believes that American innovation and economic growth will also suffer as the population gets older and smaller (Wattenberg p.73-74).

Present population trends may also affect the balance of military power. The population of nearly all communists countries is growing. The present fertility rate in the Soviet Union is 2.4 (Wattenberg p. 15). Suppose that in the year 2100 the United States, with an aging population of only 180 million is facing a hostile Soviet Union with a younger population of more than 500 million.

Under the spirit of glasnost, the Soviet Union appears less threatening at the present time. Perhaps this happy condition will continue through the next century. On the other hand, Gorbachev may be suddenly replaced by a hard line communist, as already happened in red China. No one knows what will happen in the Soviet Union in the future. It is best to be on the safe side and not depend on luck for our future security.

The communist leaders of China are attempting to level off their population at 1.5 billion, and also industrialize their nation. Perhaps they will fail; perhaps they will succeed. No one knows how things will turn out. But if they have a partial success; if they reach the industral level of the Soviet Union, they will be a formidable power. Again, it is best to be on the safe side rather than gamble with our safety.

The Cause of Low US Fertility

What is the basic cause of the low fertility rate in the United States? Wattenberg shows convincingly that it is the desire for a small family that is the main factor. People could have larger families if they wanted them. Why don't they want them ? The great publicity about the danger of a "population explosion" is one possible culprit. The fertility rate dropped below the replacement rate just after the "publicity bomb" went off around 1970. Wattenberg lists the following factors that depress fertility:

**** Randy: This should be formatted as a list, without so much white space

urbanization

more education

more income

more working women

more abortion due to legalization

improved birth control

delayed marriage

later birth of first child

more divorce

increased infertility

increased spinsterhood

more open homosexuality

more open lesbianism

more living together

women’s liberation

the perceived high costs of children

environmentalism

Up to now we have treated the population of the U.S. as if it were uniform, but the fertility rates are not the same for all segments of the population. Wattenberg has examined the fertility rate for various groups and has reached some interesting conclusions:

1. The birth dearth is not the fault of blacks. Black fertility is 2.2.
2. The birth dearth is not the fault of Hispanics. Their fertility is 2.4.
3. Asians are not to blame; their fertility is 2.0.

4. It is not the fault of low income families; families with income less that $10,000 per year have a fertility rate of 2.1
5. It *is* the fault of medium income families; those with incomes of $20,000 to 25,000 per year have a fertility rate of 1.7.
6. It is *mainly* the fault of high income families; those with incomes over $35,000 per year have a fertility rate of a suicidal 1.3 !

Wattenberg finds that this pattern cuts across ethnic lines. High income blacks and Hispanics also have low fertility rates. (Wattenberg p 77) Since most high income people are well educated it is probably true that educated people have an fertility rate that is too low. In fact, college-educated women have a fertility rate of 1.4 (Wattenberg p. 76).

A Personal View of The Birth Dearth

I thought it would be interesting to see if my own family was growing or declining. I took a horizontal slice across my family tree, including all people in the same generation. The generation I looked at are old enough that it is reasonably certain that all their grandchildren have been born. My relatives are nearly all college graduates or the equivalent, so they represent a middle to high income group.

grand fertility

children children rate

Males:

LD	2	4	2.0
BD	2	5	2.5
EK	2	5	2.5
GG	2	2	1.0
RL	2	3	1.5
TL	3	3	1.5

Females:

HK	3	0	0.0
LK	2	4	2.0
FC	1	3	1.5
EG	2	3	1.5
LF	2	1	0.5
HF	0	0	0.0
MG	0	0	0.0
FD	2	9	4.5
CD	0	0	0.0
ND	0	0	0.0
DL	1	2	1.0
JM	4	4	2.0
LR	1	2	1.0
HC	1	2	1.0
Average Fertility			1.30

average for men = 1.83 average for women = 1.07

Most of the children and grandchildren tabulated above were born *before* the birth dearth period. It is reasonable to assume that the current fertility of this group is even lower than 1.30. You can use Pop15 to find out how many years it takes for a population to half its numbers at a fertility of 1.30. My family is an endangered species. How is yours doing?

Here is an interesting problem. Assume that your family is like mine and has been declining at a fertility rate of 1.3 for the past 50 years. Assume that your family had zero population momentum at the start of the decline. Then what fertility rate is needed to make up the lost numbers during the next 50 years?

Since 1.3 is below the replacement rate by 0.8, it might seem logical that 2.1 + 0.8 = 2.9 is the correct fertility rate. However, we must also overcome the negative momentum that has been build up during the decline. A larger fertility is needed.

This problem can be solved as follows: Select **Open** from the **File** menu. Then select the file “Static Pop.” This will load the static population which has zero momentum. Select the **Rescale** command, and then advance by one year to get the correct totals. Write down the year and the total population. Then set the fertility to 1.3 and advance 50 years. This represents the present condition of your family. Note that the total population has declined by about 33 percent, and a negative momentum has been built up. Now set the fertility to 3.0 and advance 50 years. You will see that the total population has not yet recovered; in fact it has actually declined. It will require another 35 years (a total of 85 years) at a fertility of 3.0 to restore total population to the starting value.

The correct fertility needed to restore the total population of your family to the original value within 50 years is just a tiny bit over 4.0. This value is needed, not to grow, but only to recover lost numbers. However, your family would have a positive momentum at the end of this period, so it would be in a good position to grow in the future.

I suspect that many people make a simple mathematical error in planning how many children to have. They reason that if every family has two children, then the population will remain stable. They overlook the fact that about 12 percent of people will be unable to have any children at all, and that about 13 percent will have only one child and then be unable to have any more. Taking these factors into account, the remaining 75 percent, those who are able to have at least 2 children, must average 2.63 children, to make up for those who are out of the race. If everyone plans to have two children, the human race will die out. If 30 percent of people plan to have two children, and 70 percent plan to have three, then we will be just barely above the replacement rate. In other words, bare survival means that the *typical* family must have at least three children. (The situation may be even worse for well educated people. Since they usually wait longer before getting married, and since infertility increases with age. My own family tree shows 20 percent, with zero children.)

Remember, this is just to break even, just to survive, not to make any gains.

If your family is like mine, and you want to make up for lost ground, as discussed above, the same principle applies. If each person plans to have 4 children, the group average will be less than 4.0 because you must expect some infertility. Each person should aim to have about 5 children, if he can, to reach an average of 4.0.

III. The Population Panic

Malthus, writing in the time of George Washington, was perhaps the first to assert that population would outgrow food supplies, and we would all starve (Malthus 1798). History proved him wrong and his false theories were almost forgotten.

Prior to 1968 almost everyone considered a growing population to be a healthy one. Then the great population panic began. The ghost of Malthus walked the earth. Books like “The Population Bomb” (Ehrlich 1968) and “The Limits to Growth” (Meadows 1972) claimed that disaster from overpopulation was just around to corner. Movies and TV shows climbed on the band wagon and we were shown a future world in which people were jammed together like rats in a cage. In the movie “Soylent Green” food supplies gave out and a form of cannibalism was used to prevent widespread starvation. Books were written to promote the idea of a small family. One book tells us that “the perfect family” has just one child (Carlson, 1985). Another book claims that people will be happier if they choose to have no children at all (Silverman 1971).

In all this publicity and excitement, hardly anyone noticed that the real experts, the demographers, economists, and agricultural experts, did not all agree that overpopulation was a danger. The reader may be surprised to hear this, but we must remember that sensational disasters are exciting and they sell books and movie tickets. Good news often is overlooked.

Over the past twenty years there has been much rethinking. The disasters predicted by some of the panic people — food shortages, rising food prices and a rapid increase in the value of farm land, did not happen. Some of the panic people have changed their minds, others have changed the arguments that they use. There has been a general retreat by the forces of gloom and doom.

A Rough Estimate

Is overpopulation a real problem here in the USA? Let us consider a few simple facts that you probably already know. You know that the population of Red China is about 1.1 billion, and they are reasonably well fed. If you have looked at a world map you may have noticed that the land area of China is roughly the same as that of the United States. Thus it appears that the US can feed at least 1.1 billion people.

If you check a reference book, you will find that China has only 10 percent good farm land while the United States has 21 percent. This indicates that the US can feed at least 2.3 billion. This is only a quick, rough estimate. As we shall see later, a more careful estimate is much higher.

Does this mean that we would have to go to an inferior diet? No, the Chinese eat less meat that we do, but any nutritionist will tell you that this is a healthy change. The Chinese actually eat better than we do.

The fact the China is now feeding 1.1 billion people is no reason to believe that it could not feed more, if necessary. In fact, the Chinese population is still growing. It is expected to reach 1.5 billion in a few years and leaders do not foresee any problem in feeding that number. But China is a third world nation and they do not use the most productive methods of agriculture.

World Food Production

Colin Clark, a world famous economist at the University of London, has estimated that it takes 27 square meters of land to feed one person, using the best of presently known agricultural techniques. This means that the world can feed 346 billion people, and the United States, having 6.7 percent of the world's land area, can feed roughly 23 billion.

Food can actually be produced with no land at all. Twenty years ago some scientists at General Electric developed a method of growing vegetables indoors under artificial lights called Geniponics (Suran 1987). By adjusting temperature, humidity, and light to the optimal values, they were able to obtain fantastic yields from each plant. They were able to produce 100 kilograms of tomatoes per square meter per year, about five time the harvest of a conventional greenhouse. Unfortunately the method was a bit too costly to compete with dirt farming. But If the price of food rose, this indoor technique would become economical.

It is also possible to manufacture certain foods in a factory without the use of plants at all. Such factories are now used in the Soviet Union to make protein for use in food products.

These two proven techniques, Geniponics and factory production of food, were not considered by Colin Clark. Therefore his estimates of maximum world food production are clearly too low. Moreover, we have not considered the advanced technology that is likely to be developed in the future. Genetic engineering holds great promise. It is clear that 23 billion is a *very* conservative estimate of the maximum population that the United States can feed. We could quite reasonably multiply this estimate by two, or five, perhaps ten.

The Pop15 program prints in the lower right corner of the screen, a measure of "overpopulation" that we call the "Clark number." It is based of Professor Colin Clark's estimate of food production. It is the present population divided by the number of people that could be fed by dirt farming the land on which that population lives. For example, the present population of the US, 244 million, divided by 23 billion gives us a Clark number of 0.0106. This means that the present population of the US is about one percent of the number that the land can feed. In our most optimistic simulation we got the US population up to 2.8 billion, which gave us a Clark number of 0.1217; about 12 percent of the dirt farming limit.

Thus a Clark number of 1.00 means that the carrying capacity of the land is fully used. However, this is not a hard and fast limit, since food can be produced without land, and food can be imported by a nation. The true limit is unknown but might be a Clark number of 5 or 10.

The question of overpopulation involves many factors besides food production. However this is probably the most critical problem; it is perfectly clear that people must have enough to eat. We are forced to conclude that there is absolutely no danger of overpopulation in the United States as far a food production is concerned.

World Population

When we look at world population, we see a strange pattern.

Nearly all of the first world, the industrialized nations, have low fertility rates; all are below 2.1, the replacement level, except Israel and Ireland (still falling), and New Zealand which is close to 2.1 (Wattenberg, p18). Thus, nearly all of the first world is in the same situation as the US; negative population momentum is building. Some are worse off. West Germany has a fertility rate on only 1.3 (Wattenberg p. 173); the total population has been falling since 1980 (Cleveland p.650).

The second world, the Soviet Union and its satellites and former satellites in eastern Europe, have a healthy fertility rate slightly above the replacement level.

The third world, the underdeveloped nations, have high fertility rates, but those rates are falling.

The demographers have a theory to explain this strange pattern. It is called the theory of demographic transition. In the past, everyone on earth was poor, very few were educated, disease was rampant, birth and death rates were high and in balance. Population growth was positive, but very slow. In the future, everyone will be educated and rich, disease will be rare, birth and death rates will be low and in balance. But during the transition, death rates go down first, before the birth rates. Thus there is a large temporary spurt in population growth before birth rates catch up.

According to this theory, the industrial nations have finished the transition, but the third world is now in the middle. Thus, their large rates of growth are only a temporary phenomenon. If the theory is correct, world population, now 5 billion, will peak at about 15 to 35 billion around the year 2100. Note that 35 billion is only ten percent of Clark's conservative estimate of the carrying capacity of the earth. This theory was the subject of a special issue of *Scientific American* (Piel 1974). Trends in population since then continue to confirm the theory. Singer tells us, "By now there is no reason why anybody who looks at the matter at all seriously should get a wrong picture — although an ordinary citizen whose ideas were formed by information from the 1960s, or by recent but incompetent writers, could easily go wrong" (Singer p.70).

Thus the idea that the world will starve due to overpopulation is most unlikely. Some will object at this point. They will say, "Wait a minute, this cannot be right. There are starving people in this world; I have seen them on television."

It is indeed true that some people have recently faced starvation in Ethiopia, but this has nothing to do with world population; it is caused by drought and civil war. Ethiopia has a communist government. The drought provided the communists with a convenient tool to repress resistance among the people. Countries neighboring on Ethiopia suffered the same drought but their governments distributed food and there was no starvation. A change in the population of other countries would have little or no effect on conditions in Ethiopia, except, that if the population of the US was larger, we probably would have donated *more* food to Ethiopians.

Nonrenewable Resources

Some of the panic people claim that we are running out of minerals and give this as a reason for being worried about overpopulation. First, we should note that many minerals form a major part of the earth's crust. For example, there is more than enough iron to build a 1000 story steel frame building that covers the entire surface of the earth. The same may be said for aluminum, magnesium, nickel, building stone, clay, cement, sand, gravel, glass, silicon, and a number of other minerals. It is impossible to even imagine that we will ever run out of these.

Editor's Note: Are you sure you want to live in *this* future?

However, some other minerals are not so abundant. These include copper, molybdenum, cobalt, etc. Some are quite rare such as gold, platinum, iridium, etc. These materials require more careful consideration.

"Non-renewable resources" is one of favorite phrases of the gloom and doom people. They give the impression that using copper is like eating a bowl of cherries; as you nibble, the number of cherries gets smaller and smaller, finally you eat the last one, and that is the end — *no more cherries***.**

But this is not correct. The economic way of thinking, teaches us that when we run low of some material, the market price goes up and this encourages reduced consumption, mining lower grade ore, more careful use of that material, more effective recycling, and the use of substitute materials. All of these effects working together are a powerful combination. What this means is that *we will never run out of any material***,** furthermore, there *will never be a shortage of any material***;** only that the price might go up.

If this sounds a little strange, consider the case of gold. Compared to other minerals, there is very little gold on earth. It has been estimated that all of the gold ever mined on earth would form a cube about 40 feet on a side. If we pretend that gold was abundant in the past and that we then used up most of it, gold can serve as a model for a "nonrenewable resource" after it has been mostly *used up*.

Very low grade gold ore is mined. One ounce to the ton (0.0034 percent gold) is considered rich ore among miners. Gold is used very carefully. The computer on which I am writing this has gold plated contacts. Only tiny amounts of gold are used. When anything containing gold is scrapped, the gold is carefully extracted and recycled. The result is that there is no shortage of gold. You can walk into a gold dealer any day of the week and buy all the gold you want. Of course you must pay for it, and the amount that you want is influenced by the price.

Now let us imagine an extreme case. Let us assume that we really did mine all the gold on earth; There is absolutely none left in the ground. There are still at least three sources of gold that would keep a supply on the market.

(1) We would recycle the gold we already have (that was mined in the past). The price would go up and we would recycle even more carefully.

(2) We could import gold from the moon, the asteroids, or from other planets. This method has already been used on a small scale to import rocks from the moon. This is expensive, but remember that sending minerals from space to the earth is much, much easier that going from earth to space. That is because gravity helps when one is traveling to the earth.

(3) Finally, it is possible to manufacture gold from other materials by the techniques of nuclear physics. This method is very expensive, but it is used to produce Plutonium.

Some would object that we cannot use these last two methods because they are “too expensive.” Those who say this have not grasped the fundamental idea of economic thinking; the price will go up until supply and demand are in balance; until we have all the gold that we need.

We have been conservative by discussing only methods that have already been invented and used. It is also possible that entirely new methods will be discovered. Also, improvements in technology will almost certainly reduce the cost of these methods in the years ahead.

"Bowl of Cherries" thinking is an incorrect way of looking at the question of "non-renewable" resources. Economic thinking is a more sophisticated and a more correct way of looking at the problem. We never run out, we never even have shortages, it is just that the price might go up.

Therefore the question we should ask about a given mineral is not "how fast are we using it up?" but "How fast is the price going up?" When we look at the price history of various minerals, we find that the price trend is not up — it is down for almost all. The reason is that new technology is constantly being developed. We do occasionally use up a high grade deposit of some ore and are then forced to mine the lower grade ores, but lower-cost ways of mining are being discovered every year. There is a race between using up minerals and inventing new technology, and new technology is winning.

In reality, the long term cost of nearly every mineral is down. The average cost of minerals is now about 25 percent of what it was in 1880, even though the population of the US and the world more than doubled during this period (Singer p.87). Furthermore the average person used only about $170 per year worth of minerals in 1980; about one percent of average income (Singer p. 81). So, if the cost of minerals doubled or tripled, we would hardly notice it.

Waste Disposal

Some claim that we must limit population because we are running out of places to put our trash. The solution is quite simple: recycling. The recycling of aluminum is already a major industry. The recycling of other materials is growing. Again we must adopt the economic way of thinking, with a slight twist. The price of trash is sometimes negative; you don’t have to buy it; you get paid for taking it. For example, if you can think of some product to make out of old tires, your business will get paid about $1.00 for each tire you use. As we run out of dumping grounds the negative price of trash will increase. This will encourage more recycling. It will also encourage people to generate less trash, if they must pay the cost.

The Energy Crisis

Energy is also no problem, for much the same reasons. If we run out of oil, we can make gasoline out of coal. This is an old process used on a large scale in Germany during World War II. It might perhaps double the cost of gasoline.

In the long term, we can get all the energy we need from sunlight. In 1987, the Sunraycer was driven 1800 miles across the continent of Australia at an average speed of 41.6 miles per hour, winning the first long distance race for solar powered cars (Wilson). Although the Sunracer is not quite a practical car, we can reasonably expect the technology to improve. The state of California now generates about one percent of its energy needs from solar power (wind is an indirect form of solar energy). If and when we run low on oil or coal, solar technology is ready to take over, at about double the cost. But the trend is downward and costs are almost certain to fall still more in the future as technology improves.

Economic Growth

It has also been argued that a high rate of population growth prevents economic progress because society must pay the cost of raising all those children. This sounds reasonable, but there is another side to the question. As you have noticed in the simulations we did with Pop15, high fertility increases the burden of raising children (cb), but it also decreases the burden of supporting retired people (rb). Since retired people tend to cost more than children, high fertility probably *helps* economic growth. If we study nations and compare their economic success with their population growth, we notice little connection. The list below shows that income has much to do with education and industrialization and little to do with population density (Johnson 1988).

Underdeveloped nations:

	persons/sq mi	income/person
Guinea	58	$293
India	582	150
Bangladesh	1740	119

Industrial nations:

Australia	5	$9900
United States	65	11,675
Denmark	307	12,956
United Kingdom	596	7216
Japan	822	8460
Netherlands	1094	9175

A study done to find the correlation between population growth and economic growth found that the correlation in industrial nations was almost zero, but in poor nations the correlation was small, but

positive. Countries with a small population growth, under two percent per year, had a median economic growth of 1.1 percent per year. Countries with the highest population growth, above three percent per year, had a median economic growth of 1.8 percent per year (Kasun p. 51).

Pollution

Some of the population panic people argue that a larger population along with economic growth and advances in technology inevitably mean greater pollution of all types. Therefore we must restrict population growth or die from excessive pollution.

Technology can provide the means to control all forms of pollution (at a price). In the late sixties we were told by the gloom and doom crowd that Lake Erie was “permanently dead.” But the fish have returned to the lake now. In reality, pollution has been falling in recent years. The air in Los Angeles is more pure now than it was in the 1960s.

IV. The Other Side

Some readers may suspect that I am presenting here only one side of the story, and that the other side has opposite opinions and equally persuasive arguments. The other side does indeed have a different opinion. But when we carefully study what they are saying, we find that they are long on salesmanship, but short on hard facts and solid arguments.

The Lifeboat Analogy

Consider the famous lifeboat analogy. In 1974 Garrett Harden likened to Earth to a lifeboat, which has a number painted on the side to indicate its maximum carrying capacity (Hardin 1974). This lifeboat analogy was a masterpiece of dramatic imagery and has been widely quoted, but few seem to have noticed a curious omission.

Harden did not give any number for the carrying capacity, not even a rough estimate. He gave the impression that world population was rapidly approaching the limit, but gave no numbers. From the tone of Harden's article one might get the impression that the sign on Lifeboat Earth said "Absolute Maximum Capacity 6 Persons," and that the boat already contained 4 persons with hundreds more clambering to get aboard.

But as we have seen, the capacity of the Earth is very large in relation to the present population. Moreover, we cannot set any hard and fast limit. Dirt farming gives us one number, but the possibility of artificial food production allows us to double that number or more. Then when we consider the wild card of future technical progress, the concept of a definite limit seems very hard to pin down.

A more accurate version of Garrett Hardin lifeboat vision would look like this: The sign on the life boat says "Capacity About 346 to 700 or Maybe More" and the boat presently holds 5 people, with the prospect that perhaps 30 more will come aboard. Garrett Hardin himself now accepts Clark's estimate that the earth can feed 346 billion. (Hardin 1988 p. 8)

In the early 1970s, the two Meadows (husband and wife) published a book called "The Limits to Growth." The sales blurb on the cover reads, "A world where industrial production has sunk to zero. Where air, sea and land are polluted beyond redemption. Where civilization is a distant memory."

The book described a computer simulation of world population and its relation to food, industry, and pollution. People are often impressed by numbers that come out of a computer, but bad assumptions lead to false results, whether one uses a computer or just pencil and paper.

A key part of the Meadows simulation was the relation between wealth and fertility. The experience all over the world has been that increasing wealth leads to decreasing fertility. But the Meadows program used the Spengler theory, which asserted that, after a certain point there would be a reversal; increasing wealth would cause increased fertility, a purely theoretical idea. The Spengler theory was radical and doubtful even in 1972; we now know that it is wrong.

The Meadows used several other controversial assumptions, but 18 years of history since 1972 have clearly shown that nearly all the predictions of the Meadows computer program are wrong. We award the Meadows an A for lurid and effective publicity, but an F for accuracy.

This is a good place to point out that the Pop15 program has very little in common with the elaborate Meadows simulation. Pop15 simply computes the natural increase (or decrease) of a population taking the age structure of that population into account. It contains no radical or controversial assumptions.

Exponential Growth

Part of the population panic seems to be based on a very simple misunderstanding of population dynamics. Many writers use the mathematics of exponential growth to predict future changes in population. They make the tacit assumption that if a given population is growing at, say, one percent per year now, and if nothing changes, then that population will continue to grow at one percent every year in the future. This assumption is wrong because it overlooks the effect of population momentum.

For example, one reference book says that the current fertility of the US is 1.8 and the “doubling time” for the total population is 78 years (Cleveland p. 772). It would appear that this “doubling time” is based on the mathematics of exponential growth. Most people reading the reference book would assume it means that if the fertility remains constant at 1.8, then the total US population will double in 78 years. Now that we have run Pop15, we know that this quite wrong. We know that if fertility remains at 1.8, the total population will rise slightly and then begin to decline. Population will not double but will actually fall in 78 years. This misleading information appears, not in a cheap tabloid newspaper, but in no less an authority than the Encyclopedia Britannica. Pop15 was written to help correct this type of misunderstanding.

The mathematics of exponential growth describes a colony of bacteria reasonably well (because the age of a bacterium is not important), but it can be very misleading when applied to human populations. The existence of such misinformation makes it is easy to understand why many believers in zero population growth assume that, since the US population is still growing, fertility is too high and should be reduced.

V. Conclusions

The good news is that the gloom and doom people are wrong on every point. All over the world, people are getting wiser, richer, and healthier. The production of food, minerals, and other goods per person is going up; the cost is going down. We will never have to go to war over a dwindling supply of anything. There is plenty for everyone.

World population is growing rapidly, but there is every reason to believe that this is a temporary condition. Fertility rates are falling all over the world. World population is expected to level off at about 15 to 35 billion. It is estimated that the earth can feed 385 billion, even without the use of advanced technology. Nobody is in starving or ever likely to starve, except for political problems in local areas. There is no reason to be worried about the overpopulation of the world. There is even less reason to worry about the danger of overpopulation in the United States.

The bad news is that the fertility rate in the United States is too low. We are heading for trouble unless we increase our fertility at least to the replacement rate of 2.1, and preferably somewhat higher than this. Wattenberg thinks 2.2 is about right. I would favor about 3.0; Those who wonder if we can support such a larger fertility should note that the US fertility rate was 3.7 during the baby boom of the 1950s (Wattenberg p. 16).

According to preliminary estimates there has been a slight increase in fertility in the United States in 1988 and 1989 (Wattenberg 1990). Fertility is still below the replacement rate, but it is a hopeful sign. Unfortunately the fertility of high income Americans is still *far* below the replacement rate.

One consequence of present demographic trends is that minority groups are growing relative to the rest of the population and they will be the majority in the future. Non-Hispanic whites made up 90 percent of the US population until 1955. They are now down to about 75 percent and falling. If present trends continue, whites will become a minority of the total population by about 2056 (Henry p. 30). Of course, whites will become a minority of the number of babies born each year much sooner than this. In California, whites are already a minority of the school-age population (Henry p.29).

It is important to realize that fertility is mainly a function of income level and has little to do with race. The same trend of fertility falling with income cuts across all ethnic lines. Thus the birth dearth has nothing, directly, to do with race. Unfortunately, many people do not know this and the relative increase in the number of non-whites may be causing racial tension that is quite unwarranted. Many whites that I have talked to see the problem as non-whites having too many babies. They do not realize that the problem is actually that whites are having too few babies. Once the true nature of the problem is understood, it is clear that whites can correct the problem themselves simply by having more babies.

Few population experts see any reason to be concerned about overpopulation. But many ordinary citizens are worried because they have been misled by the “population panic people,” a small but influential group or writers, newsmen, film makers, and political activists. These people have distorted reality , perhaps because sensationalism sells books and movie tickets. Some appear to have been motivated by political ideology.

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