Gonorrhea, Infertility and Population Decline in Yap during the Japanese Occupation

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As outlined in a previous papers regarding population dynamics and labor during the Japanese occupation of the Micronesian islands (Cassels 2003a; Cassels 2003b)**,** disease in Micronesia facilitated by the Japanese during their occupation from 1919 to 1945 had a large impact on native population growth. The overall native population in Micronesia was stagnant during the Japanese occupation, but the population on Yap declined drastically. Population decline resulted from low birth rates and high death rates. The objective of this paper is to predict how much gonorrhea affected population growth, and determine the underlying causes and modes of transmission of the gonorrhea epidemic in Micronesia during the Japanese occupation. We use data from the island of Yap, but the results could later be used to predict the impact of gonorrhea on population growth throughout Micronesia during this time.

Many theoretical and empirical papers have attempted to calculate the impact of gonorrhea on population growth (Arya, Taber, and Nsanze 1980; Garnett and Anderson 1993; Garnett, Swinton, Brunham, and Anderson 1992; Hethcote and Yorke 1984; Kramer and Reynolds 1981; Swinton, Garnett, Brunham, and Anderson 1992). Additionally, gonorrhea, along with tuberculosis, have been identified as the leading causes of depopulation on Yap (Gorenflo and Levin 1991; Lessa and Myers 1962; Peattie 1988; Pirie 1972). The present paper contributes to both sets of literature in many important ways. The data from Yap provide a glimpse into uninhibited transmission and infection of gonorrhea since no form of treatment was available at the time. Therefore, a true estimate of the unrestrained impact of gonorrhea infection on population growth can be assessed. The island of Yap was quite isolated, and fairly closed regarding migration, except for the movement of young male workers recruited to work at phosphate mines in another district of Micronesia. Only a few outsiders, including around 240 Japanese, lived with the natives on the island in 1930. This unique situation allows us to trace the transmission of gonorrhea, and see how Japanese colonialism contributed to the depopulation of Yap. Hence this paper goes one step farther than the previous literature: To calculate the impact of gonorrhea on population growth, and identify the proximate causes of gonorrhea transmission on Yap.

3.1 The nature of the disease

Gonorrhea is a venereal disease caused by *Neisseria gonorrhoeae*, a bacterium that can grow and multiply easily in mucous membranes of the body. In women, symptoms are often mild or unnoticeable; the majority of men experience burning sensations while urinating and have discharge from the penis. If untreated, which was often the case before antibiotics, gonorrhea infection can lead to pelvic inflammatory disease (PID) in women, which then may lead to infertility. The probability that a women becomes infertile without treatment is the product of the proportion of infections leading to PID (0.2) and the probability that PID leads to infertility (0.6) which equals 0.12 (Swinton et al. 1992).

3.2 Gonorrhea in Micronesia

The exact date that gonorrhea was introduced to Micronesia is uncertain. Records indicate that gonorrhea was transmitted to many islanders during early foreign contact. In 1791, gonorrhea was already established in Palau, for three Palauan women who were taken upon a British ship transmitted the disease (Hezel 1983). Ponape and Kosrae's populations were devastated by gonorrhea spread by whaling ships. "Hardly a native is free from it" wrote a captain of a British warship after visiting Kosrae in 1853 (Hezel 1983). Trading vessels reached Jaluit (the Marshall Islands) in 1860, and venereal disease spread rapidly in the years following, for many traded their wives' "favors" to seamen for tangible goods (Hezel 1983). Yet, since Micronesia is so vast and isolated, the time and extent of introduction varied by island, proximity and the extent of contact with foreigners. In 1880, Palau's population was decreasing drastically due to gonorrhea: only 2 in 5 women bore children, and a family with 2 or 3 children was considered large (Hezel 1983). But at this time Yap's birthrate remained steady, and their population was double that of Palau. Thus, we do not know when gonorrhea reached Yap, but it seems that the impact of gonorrhea on population growth on Yap came much later than on Palau, Ponape and Jaluit (Marshall Islands) and possibly not until major colonialization activities in the early 1900's.

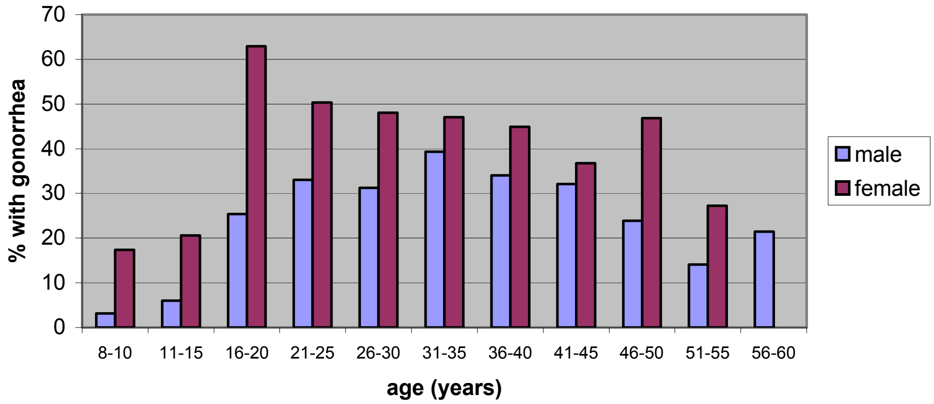
During the Japanese occupation, venereal disease was prominent among patients with infectious disease, which made up about 10% of native and Japanese hospital patients. For example, out of 100 patients with infectious disease in 1926, 40 were treated for venereal disease—30 of these were for gonorrhea (South Seas Government 1920-1937). These numbers varied by year, depending on other disease outbreaks. Furthermore, many gonorrhea cases were likely unreported as many natives did not go to hospitals for treatment, and gonorrheal infections were often undetected.

In the early years of the Japanese occupation little to no cases of gonorrhea were reported on Yap, clearly a case of underreporting. Nonetheless, Yap was gaining international attention because the native population was drastically decreasing. In 1924, the native population on Yap was 7,523. Five years later, the native population had decreased by more than 13% reaching 6,545 people in 1929, and was still falling. The League of Nations ordered Japan to investigate the cause of the population decline; thus an in-depth study of native health on Yap began in 1929, led by Dr. Fujii, the director of the Yap hospital. He carefully examined almost all of the inhabitants on the main island of Yap from 1929 to 1930. Dr. Fujii concluded that the decrease in population was due to a high death rate caused mostly by tuberculosis, and a low birth rate resulting from gonorrhea. In fact, gonorrhea infections on Yap reached endemic proportions. We will use data from this study to model the impact of gonorrhea on fertility and population growth.

Dr. Fujii examined 2,354 of the 3,884 Kanaka natives living on Yap (main) island for gonorrhea in 1930. His results were shocking. He found 312, or 25% of males suffering from gonorrhea, and 472, or 43% of women with gonorrhea. Of the 312 males, 289 had chronic gonorrheal inflammation of the urinary passage, 18 with acute inflammation, and 5 with gonorrheal epipidymitis. 239 women were found to have gonorrheal inflammation of the membrane lining the uterus, 111 with inflammation of the urinary passage, 85 with gonorrheal catarrh of cervix uteri, 19 with acute inflammation of the urinary passage, 15 with gonorrheal inflammation of the vagina, and 5 with inflammation of Bartholin's gland (South Seas Government 1920-1937).

Figure 1 depicts the percentage of natives suffering from gonorrhea by age. No patients under eight years old were examined. Young women had the highest gonorrhea prevalence, reaching 63% of women aged 16-20 and 51% of women aged 20-25 (South Seas Government 1920-1937). The prevalence of gonorrhea in men peaked later than women, in the age-class 31-35 years (39%).

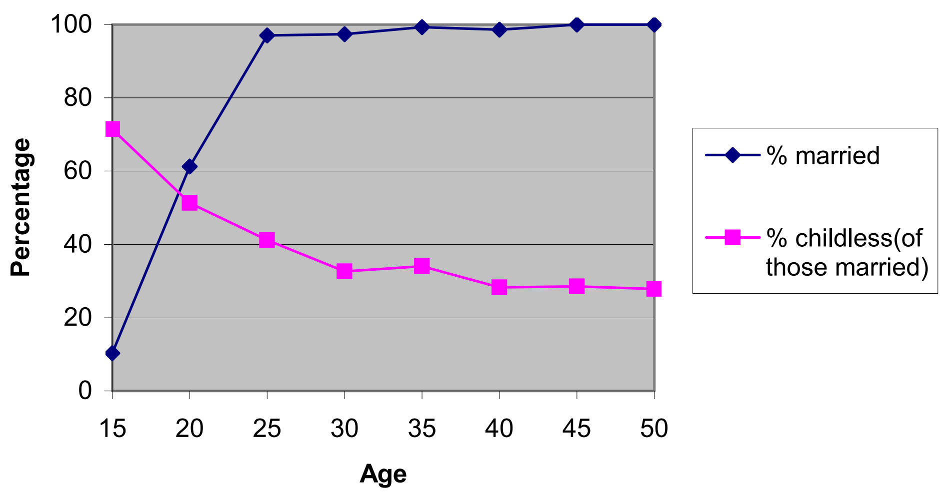
Figure 1: Age distribution of men and women with gonorrhea on the main island of Yap in 1930.



Source: (South Seas Government 1920-1937)

Marriage and childlessness data also suggest that infertility was prevalent among Yap natives. Figure 2 shows that by age 25, almost all women were married already, but almost 30% of couples remained childless.

Figure 2: Percentage of married women by age, and the percentage of married women who had never conceived.



Source: (South Seas Government 1920-1937)

Thus we see that gonorrhea was prevalent, as was infertility. The purpose of this paper is to determine the magnitude of the impact of gonorrhea on population growth and the underlying causes of the gonorrhea epidemic.

3.3 A model of gonorrhea transmission

Compartmental mathematical models have been used in the past to explore the relationship between gonorrhea, infertility and population growth in sub-Saharan Africa (Swinton et al. 1992) (Brunham, Gernett, Swinton, and Anderson 1992; Garnett and Anderson 1993; Garnett et al. 1992; Hethcote and Yorke 1984; Zaba and Campbell 1994). In these models, a set of ordinary differential equations describes how individuals move between states of susceptibility and infection.

These models do not incorporate age specific fertility or mortality, which is an unrealistic simplifying assumption (Zaba and Campbell 1994). A simulation model, on the other hand, can incorporate many small details while remaining fairly simple and straightforward. We base our model on the compartmental models mentioned above, but introduce age-specific variability in the parameters and specify the model according to the conditions in Yap during the Japanese occupation. In this model of gonorrhea and reproduction, we vary relevant parameters and assess their importance to fertility. Ultimately, we vary levels of sterility and conclude how much infertility from gonorrhea affects the birth rate and thus population growth. Nonetheless, conclusions from a simulation model—as with any model—are only as reliable as the assumptions and parameters which the model takes in (Wachter 1987).

The present analysis uses a Monte Carlo simulation model, meaning that random numbers are used to predict when an event will occur by means of probabilities, such as the probability that a woman will conceive or that the conception will end in a live-birth or miscarriage. In this initial simulation, the reproductive history of a cohort of women is simulated from the beginning of marriage to the end of the reproductive span. Characteristics of each woman, and aggregated characteristics for the entire cohort, are recorded. We use data specifically from Yap in 1930: mortality data, age at marriage, and gonorrhea prevalence. Data for other parameters, such as the probability of conception, are borrowed from reproduction literature. The goal of the simulation is to estimate how much population growth is depressed due to gonorrhea-induced infertility.

Figure 3 summarizes the simulated events. The time variable is discrete, cut in one month intervals. Months are bracketed into larger groups, mostly five years long. Events including marriage, mortality and infertility happen at the beginning of these larger time intervals. If the individual survives, then she continues through the interval, month by month, and is subject to reproductive events.

[Insert Figure 3 about here]

For example, before a woman enters the stage 20 to 25, she is subject to age-specific events: marriage, mortality and risk of infertility due to gonorrhea. The probability that a woman age 20 dies before age 25 is 0.061. To see whether she survives in our model, a uniformly distributed random number between 0 and 1 is generated. If the number is less than 0.061 then the woman dies, and her characteristics are recorded. If the number is greater than 0.061, then she survives and is subject to marriage and infertility. According to the data, 97% of women were married by age 25. If the individual marries at the beginning of this stage, i.e. if another random number is less than 0.97, then she is subject to infertility and then month to month conception. If she does not marry, she is still subject to becoming infertile, but will not face the risk of conception until age 25. In the year 1930, 50.3% of women living in Yap aged 20-25 suffered from gonorrhea. Without treatment, 12% of women suffering from gonorrhea become infertile. Therefore, in our model, a woman aged 20 has a 6% chance of becoming infertile before the age of 25. If the woman survives, marries and does not become infertile, then she enters the 5 year cycle, facing the month-to-month risk of conceiving. If she becomes infertile, then she drops out of the simulation, and her characteristics are recorded.

The probability of conception is p per month. A random number generator with a geometric distribution and mean p is used to predict how many months the woman waits until her next conception. As mentioned, if she dies or becomes infertile, then she drops out of the simulation and her number of births (if any) are recorded. If she conceives in any given month, then the conception ends in either a miscarriage, with probability θ, or a live birth, with probability $1 - \theta$. We assume that a woman will be infertile for $s1$ months after conception if she has a miscarriage, while a live birth keeps the woman insusceptible to conception for $s2$ months: the duration of pregnancy (9 months) plus the duration of post-partum amenorrhea. Once the woman ages to the next age-group, she faces age-specific mortality and infertility risk again, then continues through the month-to-month risk of conception until she either dies, becomes infertile due to gonorrhea, or ends her reproductive life span at age b. Each simulation consists of a cohort of 1000 women, and summary statistics for the entire cohort include the number of deaths, infertile women, and births.

The model does not allow marriage dissolution or homosexuality. Births are not allowed until marriage, although sexual activity and the risk of infertility is. Reasoning for this is as follows: Young girls were having sex in Yap by ages 8-10 because we know some of them already suffered from gonorrhea; however a girl that age most likely is physically unable to give birth. Additionally, historical accounts mention that sexual intercourse was indulged in excessively, thus enabling gonorrhea to spread without marriage. Thus, our assumption is that if a woman conceives, than she marries (in the model the order is opposite, but the difference is moot); otherwise conception is somehow avoided.

3.4 Results

The first run is a baseline model (see Table 1, model 1). This run was meant to provide a glimpse of uninhibited fertility: no miscarriage, no temporary infertility from breastfeeding amenorrhea, and no contraception. Each woman is subject to age-specific mortality, as women were on Yap during 1930. All women begin reproducing at age 15 and stop at age 40 in the baseline run. The monthly probability of conception is 0.2. The results of later runs can be compared to the baseline to evaluate parameter sensitivity.

[Insert Table 1 about here]

The expected monthly birth rate, according to renewal theory[1] and the parameters from our baseline model, would be 0.0714. This translates to 21,420 births for our cohort of 1000 women over a reproductive period of 300 months. The baseline run, without gonorrhea-induced sterility but with female mortality up to age 40, resulted in 12,961 births. Therefore, mortality alone reduced the birth rate by almost 40%.

Now we introduce gonorrhea-induced sterility. In the baseline model, births decreased from 12,961 to 10,249. Translating the number of births to the net reproductive rate (NRR), gonorrhea-induced sterility reduced the NRR from 6.33 to 5.01, a 21% reduction. The NRR is a valuable measure, since it represents the average number of female offspring a woman can expect to have in her lifetime. Unlike the total fertility rate, the NRR incorporates both age-specific fertility and mortality rates. A NRR > 1 implies a growing population, while NRR < 1 means the population is shrinking.

Models 2 through 6 show how sensitive certain parameters are. Consistent with well known results, increasing the length of post-partum amenorrhea greatly reduces the net reproductive ratio. In fact, it is the most sensitive parameter in the model. Comparing model 2 with model 1 shows that introducing 12 months of post-partum amenorrhea decreases the NRR by 47%. Additionally, contraception reduces the birth rate, but the relative reduction in the birth rate is always less than the efficacy of contraception. For example, say that 100% of women practiced the withdrawal method, and it was 50% effective. Then the monthly probability of conception would be (0.2)*(1 - 0.50) = 0.1. Comparing model 3 with model 1, we see that changing the monthly probability of conception from 0.2 to 0.1, while keeping the rest of the parameters constant, results in a 24% drop in NRR. Model 4 introduces the chance of a conception ending in miscarriage 10% of the time; this results in only a 1% drop in the NRR. In model 5, the age of marriage, or entry into risk of conception, is no longer constant. Rather, 10% of individuals marry before age 15, 62% before 20, 97% before age 25, and everyone is married by age 30 as was the trend on Yap in 1930. The NRR in model 5 is 10% lower than in the baseline model. Finally, in model 6 we experiment with the age of menopause. As shown in Figure 2, the percent of childless women remains fairly constant after age 35, thus ending risk of conception at age 35 is reasonable. The NRR in model 6 is 15% lower than in model 1.

During the Japanese occupation before WWII, the growth rate in Yap was negative implying an NRR less than one. Thus, in models 7 through 11, parameters are varied in order to see which combinations could reproduce an NRR near or below one. Historical reports mention that husband and wife did not engage in sexual intercourse *at least* one year after birth (South Seas Government 1920-1937), thus a postpartum amenorrhea of 12 months is logical and perhaps 24 months of reduced risk of conception is reasonable. Dr. Fujii's investigation found that about 6% of conceptions end in miscarriage or still birth, but we experiment with higher percentages in case that miscarriages were unreported. On average, an individual in our simulation was not at risk for another conception for three months if her conception ended in miscarriage. Finally, age at menopause was varied from 40 years down to 30. In model 10, the

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[1] $$\mu(t) = \frac{1-\theta}{\frac{1}{p} + (1-\theta)*s2 + \theta*s1}$$

NRR is 1.04, a 79% drop from the baseline, and in model 11, the NRR is below one which implies a shrinking population. Thus, it is possible that the parameters in model 11 resemble reproduction and sterility on Yap in 1930.

How much did gonorrhea affect population growth? No matter which combination of parameters were used, the percent drop in NRR from gonorrhea-induced sterility was always around 20%. The difference ranged from 15% in model 10 to nearly 25% in model 5. Most deviations from the average were due to the stochasticity of the model, i.e. variable numbers of dead and/or infertile women. A 20% drop is much lower than some published results (Brunham et al. 1992), who found a 72% drop in total fertility rates due to gonorrhea-induced infertility, but consistent with a simulation model where mortality and fertility rates varied by age (Zaba and Campbell 1994).

Models 10 and 11 result in a NRR near one, but before gonorrhea-induced fertility was included in the model, the NRR was near 1.2. Therefore, it is possible that affect of gonorrhea-induced sterility was great enough to reverse the sign of population growth *assuming* the simulation model sufficiently resembles reproductive life in Yap during the Japanese occupation.

3.5 Disease transmission

Why was the population on Yap decreasing so rapidly while native populations on other islands in Micronesia were either relatively stagnant or slightly increasing? Were conditions on Yap different than on the other island districts? We propose three unique trends that contributed to continued gonorrhea prevalence, low fertility and depopulation. First, Yapese society was unique; they had very strong tribal practices and customs (Hunt, Kidder, and Schneider 1954). Native Yapese refused to associate with the Japanese, accept much modernization, or adopt any of their cultural practices. Second, the Japanese never established much of a presence on Yap. Third, Yapese were heavily recruited to work in the Angaur mines: Increased mobility led to higher disease prevalence. Next I will explain how and why these three trends affected gonorrhea prevalence.

The Yapese with their rich culture were the most stubbornly resistant to change introduced by the Japanese. When the Japanese were forced to turn their attention to the population problem in Yap, they concluded that because of Yapese stubbornness to accept modernization, the solution was to break down tribal customs and practices, and increase their efforts to improve medical care. They believed Yapese customs were retarding intervention (U.S. Navy 1948), such as refusal to adopt western clothing (they preferred loincloths and grass skirts), refusal to adopt modern homes (their houses were dark and poorly ventilated), and hesitancy to seek modern solutions to medical problems. Consequences of Japanese action were twofold: increased resistance to change, and weakened traditional society. Both proved detrimental to native health. Japanese efforts to improve medical care did not yield improved health status because the natives believed that the Japanese simply intended to abolish all Yapese customs. Weakened traditional society threw native life into a downward spiral; social controls were undermined, family life became disorganized, and traditional morals were compromised leading to the spread of venereal disease (Peattie 1988).

Secondly, unlike the Spaniards, large numbers of Japanese never settled on Yap. The seaport in Yap received the least business out of all the districts, and native school attendance was the second lowest after Jaluit, where geographical considerations made school attendance difficult (South Seas Government 1920-1937). In fact, the South Seas government repeatedly claimed that since very few Japanese lived on Yap, high incidence of disease was not due to contact with "advanced people". Additionally, they highlighted the fact that in districts with large numbers of Japanese colonists, native population grew steadily, as on Palau (South Seas Government 1920-1937). The lack of a large Japanese community may seem like it should have been a lucky break for Yap, however the opposite effect prevailed. First, disease had already been introduced to the island via foreign contact. Second, they were thrown into turmoil, not able to escape all Japanese influence and live traditional lives, but not receiving many benefits of modernization either. With little income for trade, poor nutrition and little education, morbidity levels stayed high. Thirdly, some Yapese did have extensive contact with outsiders when they were recruited to work on the mines, and these contacts did have significant and lasting effects on native health.

The Japanese-run phosphate mine in Angaur (in the Palau district) relied heavily on native labor from other islands. Since the native population of Angaur was small, labor was recruited mostly from Yap and Truk. Officially, labor was optional, but in fact the Japanese government ordered strict quotas to native chiefs; they had to produce a certain number of workers from each island. Many young men of prime working age from Yap were recruited to work in the mines, which had numerous ramifications for the population. About 40% of the miners in 1926 were from Yap, which implies that 148 young men left the island of Yap to work in the Angaur mines (South Seas Government 1920-1937). Roughly, this translates into around 8% of males aged 15 to 50[2].

Losing young men from Yap affected native health in two ways. First, helping hands around Yap villages were lost which resulted in less food production, food shortages and poor nutrition (Peattie 1988). But more importantly, increased mobility resulted in more frequent contact with foreigners, as well as more inter-island contact. Systems of indentured labor, i.e. removing a high proportion of young adult males to work on commercial plantations where sexual needs were often provided by prostitutes, then allowing them to return home, have been shown to be quite favorable to the establishment and spread of gonorrhea (Brewis 1992) (Pirie 1972). Moreover, Palau had a history of clubhouse prostitution, a custom with strong roots in society. During German times, the promiscuity of the clubhouses was blamed for the rampant venereal disease and decreased fertiliy (Hezel 1995). Therefore, laborers from the phosphate mines most likely contracted gonorrhea from these clubhouses and returned home with the disease, hence contributing to the unusually low birth rate in Yap during the Japanese administration.

[2] This calculation assumes that 50% of the population is male, and another 50% of the male population is between 15 and 50 years old (Gorenflo and Levin 1991).

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Figure 3. Simulation flow chart

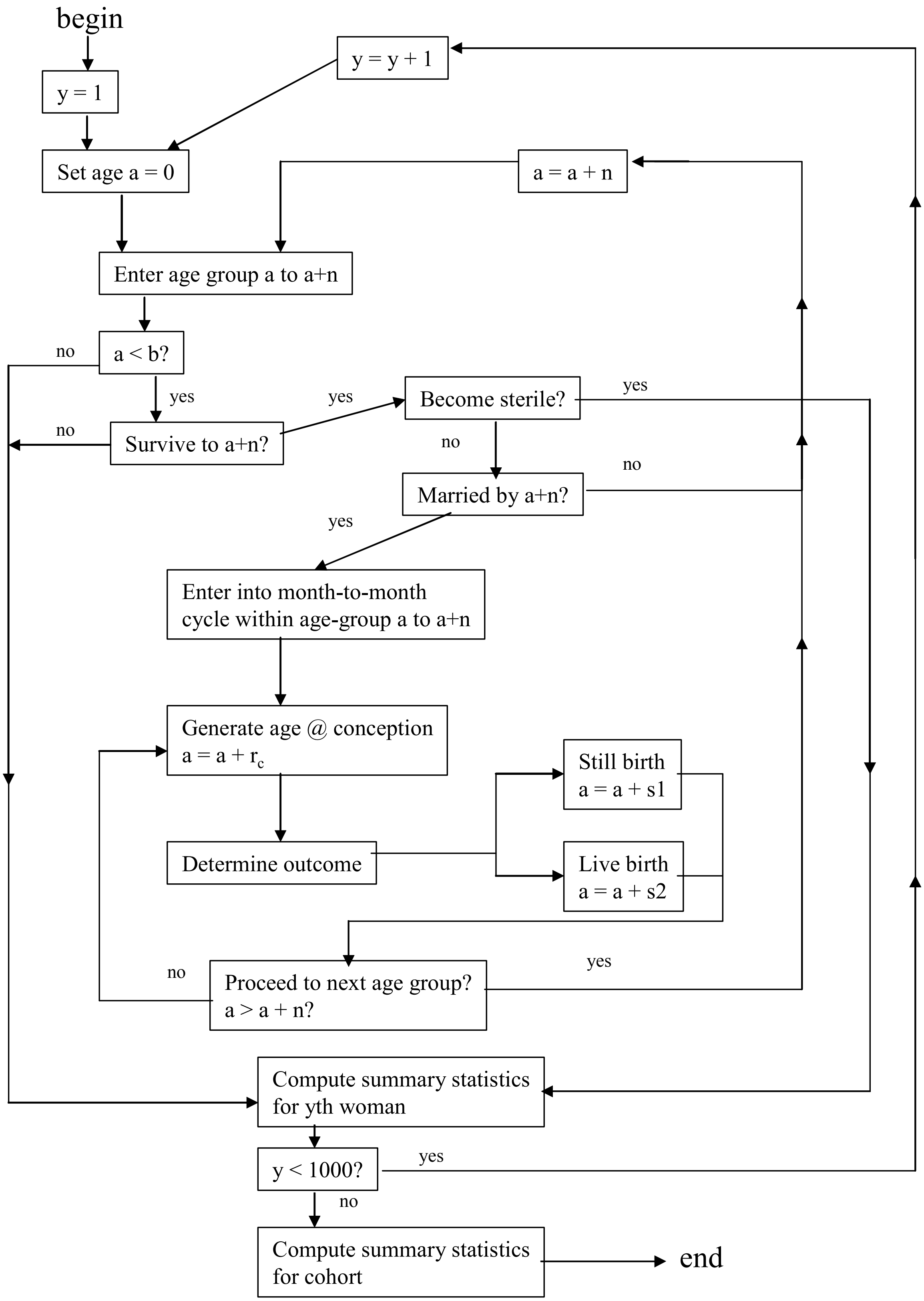

Table 1. Simulated results from a model of reproduction

Input assumptions

	model 1	*model 2*	*model 3*	*model 4*	*model 5*	*model 6*	*model 7*	*model 8*	*model 9*	*model 10*	*model 11*
Age-specific mortality	Yap pattern...										
Probability of conception (monthly)**	0.2	0.2	0.1	0.2	0.2	0.2	0.2	0.1	0.1	0.1	0.1
Probability of miscarriage	0	0	0	0.1	0	0	0.2	0.2	0.2	0.2	0.3
Infertility after miscarriage (months)	3	3	3	3	3	3	3	3	3	3	3
Postpartum amenorrhea (months)	0	12	0	0	0	0	12	24	24	24	24
Age at marriage	15	15	15	15	variable	15	variable	variable	variable	variable	variable
Age at menopause	40	40	40	40	40	35	40	40	35	30	30
Implications											
# births/1000 women	10,249	5,453	7,786	10,146	9,200	8,711	4,874	3,030	2,631	2,130	2,035
# women infertile/1000 women	179	175	169	185	183	156	187	180	164	139	145
# deaths/1000 women	462	480	477	438	472	444	471	474	429	382	393
% sterile among those alive at menopause	33.27	33.65	32.31	32.92	34.66	28.06	35.35	34.22	28.72	22.49	23.89
# births/1000 women without gonorrhea-induced sterility	12,961	7,146	9,206	11,883	12,246	11,158	6,415	3,922	3,284	2,513	2,423
NRR without sterility	6.33	3.49	4.50	5.81	5.98	5.45	3.13	1.92	1.60	1.23	1.18
NRR with sterility	5.01	2.66	3.80	4.96	4.50	4.26	2.38	1.48	1.29	1.04	0.99
% drop from baseline (model 1)	0.00	46.79	24.03	1.00	10.24	15.01	52.44	70.44	74.33	79.22	80.14
NRR % fall due to sterility	20.92	23.69	15.42	14.62	24.87	21.93	24.02	22.74	19.88	15.24	16.01

** Geometrically distributed delay

Notes: Variable age at marriage is: 10% by 15, 62% by 20, 97% by 25, 100% by 30.

Age-specific mortality:

${}_1q_0$	0.1396
${}_4q_1$	0.1317
${}_3q_5$	0.0058
${}_2q_8$	0.0038
${}_5q_{10}$	0.0286
${}_5q_{15}$	0.0594
${}_5q_{20}$	0.0612
${}_5q_{25}$	0.0714
${}_5q_{30}$	0.0714
${}_5q_{35}$	0.0714