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

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

Susan Cassels

Disease in Micronesia facilitated by the Japanese during their colonial 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. I 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).

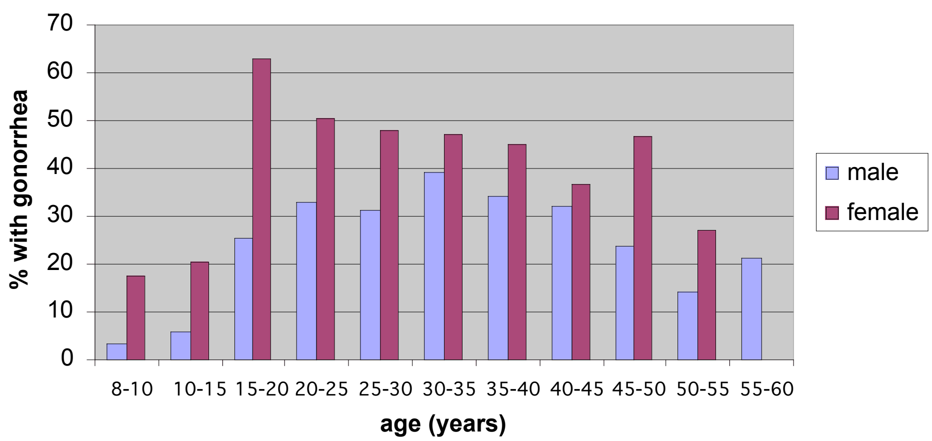
3.2 Gonorrhea in Micronesia

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, 30 were treated for venereal disease—20 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, which was clearly a case of underreporting. During these years 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, but before Fujii's study the problem had been disregarded. I 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. 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%).

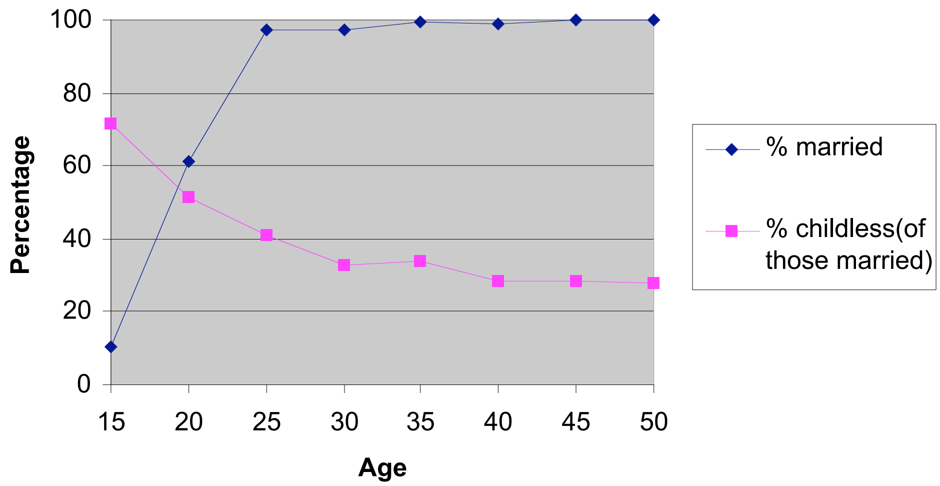
Figure 1: Age distribution of men and women with gonorrhea on the main island of Yap in 1930.



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 gonorrhea was quite 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, Garnett, 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. I base this 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, parameters are varied and their importance to fertility is assessed. Ultimately, I 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).

In this paper, the reproductive history of a cohort of women from birth to the end of the reproductive span is simulated. I use 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. Characteristics of each woman, and aggregated characteristics for the entire cohort, are recorded. I 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. (For a list of model parameters, see Table 1). The goal of the simulation is to estimate how much population growth is depressed due to gonorrhea-induced infertility.

Figure 3 shows a schematic outline of a Monte Carlo simulation model of reproduction and gonorrhea infection. The model is defined by the following rules.

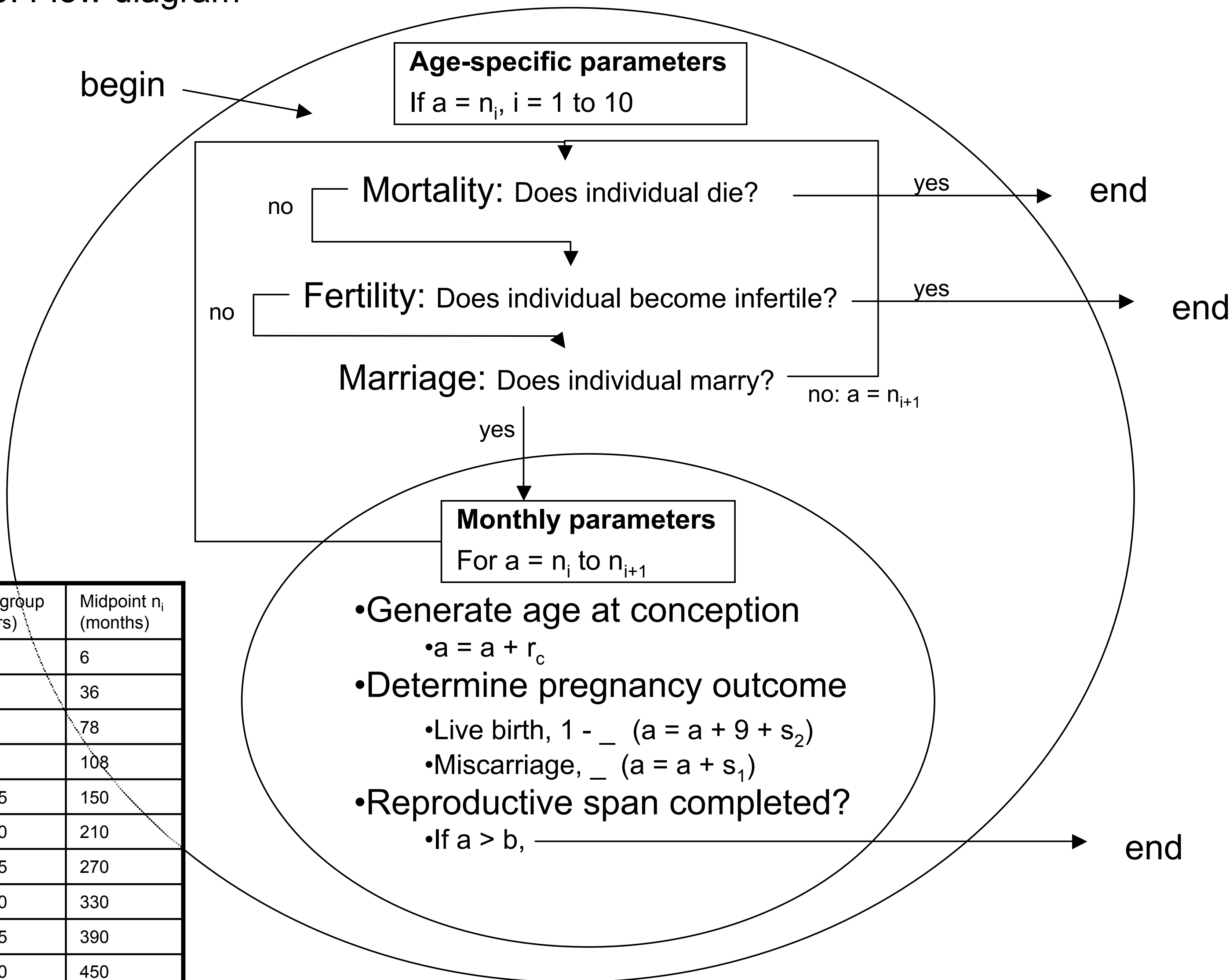
Table 1. Parameters used in simulation model

Monthly parameters		
	Monthly probability of conception	*p*
	Probability of miscarriage	_
	Length of infertility after miscarriage	s_1
	Probability of live birth	1 - _
	Length of post-partum insusceptibility	s_2
	Age of menopause	b
Age-specific parameters		
	Cumulative probability of marriage	a_x
	Probability of gonorrhea infection	${}_n m_x$
	Probability of infertility	$0.12{*}{}_n m_x$
	Mortality	${}_n q_x$

Table 2. Age-specific mortality and risk of marriage

Age-specific mortality		Cumulative risk of marriage	
${}_{1}q_{0}$	0.1396	a_{15}	0.15
${}_{4}q_{1}$	0.1317	a_{20}	0.62
${}_{3}q_{5}$	0.0058	a_{25}	0.97
${}_{2}q_{8}$	0.0038	a_{30}	1.00
${}_{5}q_{10}$	0.0286		
${}_{5}q_{15}$	0.0594		
${}_{5}q_{20}$	0.0612		
${}_{5}q_{25}$	0.0714		
${}_{5}q_{30}$	0.0714		
${}_{5}q_{35}$	0.0714		

Figure 3: Flow diagram



i	Age-group (years)	Midpoint n_i (months)
1	0-1	6
2	1-5	36
3	5-8	78
4	8-10	108
5	10-15	150
6	15-20	210
7	20-25	270
8	25-30	330
9	30-35	390
10	35-40	450

(i) A woman ages through the model in one-month intervals. Each month, she is subject to a numbered set of risks, and the outcomes affect the course of her reproductive path. For example, the question is asked: Does the woman conceive? If the answer is yes, then the question is asked: Does the conception end in a still birth or a live birth? The length of time until the women is once again susceptible to conception depends on the answer to the previous question. However, some questions, specifically regarding marriage, infertility and mortality, are only asked once in the middle of discreet age interval as opposed to every month[1]. These questions are like "pit-stops" in the model. For example, when a woman enters the 210th month (or turns 17.5 years old), she is subject to the age-specific risk of gonorrhea for 15-20 year olds. She either "survives" and continues the month-by-month reproductive process, or "dies", i.e. contracts gonorrhea *and* becomes infertile, and no longer is able to conceive[2].

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

(iii) If at each stage an individual does not die, does not become infertile, and marries, then she enters the month-by-month reproductive process. From the start of marriage, the individual is at risk of conception with probability p per month. A random number with a geometric distribution is generated, which represents the waiting time until conception. Therefore, the average waiting time is $(1- p)/p$ months and variance is $(1 – p)/p^2$. In the current model, $p = 0.2$ which

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[1] These data are taken directly from historical data from Yap in 1930; see table 2 for a list of age-specific mortality rates.

[2] The distribution of gonorrhea-risk within age-groups is not known, only the percentage of those with gonorrhea in the aggregated age-group. Therefore, instead of assuming a certain distribution, all women are subject to the probability of contracting gonorrhea at the mid-point of the age-group.

translates into an average of 4 months waiting time to conception, and is independent of time and age which is considered to be realistic for a large part of the reproductive span (Barrett 1971).

(iv) After a woman conceives, another random number is generated to determine the outcome of the pregnancy, according to the probabilities _ for a miscarriage, or 1 - _ for a live birth. If the birth is live, the individual is not at risk of another conception for the duration of pregnancy (9 months) plus an interval of insusceptibility to conception (s_2 months) following the birth. If the conception ends in a miscarriage, the individual waits for a total of s_1 months until at risk again for the next conception. This monthly cycle continues, with the interim mortality, infertility and marriage "pit-stops" until the end of the reproductive process, at age b.

(v) Each simulation consists of a cohort of 1000 women. Individual characteristics are recorded, plus summary statistics for the entire cohort, which include the number of deaths, infertile women and births. The model does not allow marriage dissolution or homosexuality.

3.4 Results

The first run is a baseline model (see Table 3, 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.

Table 3. 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*	*model 12*
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	0.1
Probability of miscarriage	0	0	0	0.1	0	0	0.2	0.2	0.2	0.2	0.2	0.3
Insusceptibility after miscarriage (months)	3	3	3	3	3	3	3	3	3	8	8	8
Insusceptibility after live birth (months)	0	12	0	0	0	0	12	24	24	24	24	24
Age at marriage	15	15	15	15	variable	15	variable	variable	variable	variable	variable	variable
Age at menopause	40	40	40	40	40	35	40	40	35	35	30	30
Implications												
# births/1000 women	9,732	5,666	7,808	9,642	9,507	7,982	5,126	3,266	2,609	2,402	1,871	1,643
# women infertile/1000 women	147	129	127	153	108	128	122	115	105	115	124	132
# deaths/1000 women	409	399	392	374	398	420	348	351	358	360	337	351
% sterile among those alive at menopause	24.87	21.46	20.89	24.44	17.94	22.07	18.71	17.72	16.36	17.97	18.70	20.34
# births/1000 women without gonorrhea-induced sterility	12,404	6,844	9,212	11,480	11,739	9,586	6,169	3,701	3,026	2,840	2,220	1,949
NRR without sterility	6.06	3.34	4.50	5.61	5.74	4.68	3.01	1.81	1.48	1.39	1.08	0.95
NRR with sterility	4.76	2.77	3.81	4.71	4.65	3.90	2.50	1.60	1.27	1.17	0.91	0.80
NRR % drop from baseline (model 1)	0.00	41.78	19.77	0.92	2.31	17.98	47.33	66.44	73.19	75.32	80.77	83.12
NRR % fall due to sterility	21.54	17.21	15.24	16.01	19.01	16.73	16.91	11.75	13.78	15.42	15.72	15.70

** Geometrically distributed delay

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 12,404 births. Therefore, mortality alone reduced the birth rate by about 42%.

Now I introduce gonorrhea-induced sterility. In the baseline model, births decreased from 12,404 to 9,732. Translating the number of births to the net reproductive rate (NRR), gonorrhea-induced sterility reduced the NRR from 6.06 to 4.76, 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 42%. 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, I 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 20% drop in NRR. Model 4 introduces the chance of a conception ending in miscarriage 10% of the time; this results in less than a 1% drop in the NRR. In model 5, the age of marriage, or entry into risk of conception, is no longer constant at age 15. 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 2% lower than in the baseline model. Finally, in model 6 I experiment with the age of menopause. As shown in

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

where _ is the probability of a miscarriage, *p* is the monthly probability of conception, s1 and s2 are the months of insusceptibility to conception following a miscarriage and live birth, respectively.

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 18% 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 13, 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 insusceptibility of conception is reasonable. Dr. Fujii's investigation found that about 6% of conceptions end in miscarriage or still birth, but I experiment with higher percentages in case some 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, but this length is increased to account for still births and late miscarriages. 8 months could reasonably represent the average time involved in an early or late miscarriage, or a still birth, and the subsequent insusceptibility. Finally, age at menopause was varied from 40 years down to 30, since not many women are having children after thirty (see Figure 2). In model 10, the NRR is 1.17, a 75% drop from the baseline, and in models 11and 12, the NRR is below one which implies a shrinking population.

Thus, it is possible that the parameters in models 11 and 12 resemble reproduction and sterility on Yap in 1930. However the percentage of sterile women alive at the end of reproduction only vary from 16 to 25%, but Figure 2 shows that near 30% of women remain childless. All childless women are not necessarily sterile, but the disparity between the two figures suggests that the present simulation model might underestimate the impact of gonorrhea on population growth.

How much did gonorrhea affect population growth? Depending on the combination of parameters used, the percent drop in NRR from gonorrhea-induced sterility varied from 12% in model 8 to nearly 22% in the baseline model. Most deviations from the average were due to the stochasticity of the model, i.e. variable numbers of dead and/or infertile women between the model runs with and without sterility. 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 11 and 12 result in a NRR below one, but before gonorrhea-induced fertility was included in the model, the NRR was near or above one. 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.

3.1 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? I propose two 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 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 two trends affected gonorrhea prevalence.

The Yapese, with their rich culture, were 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).

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 one in ten 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. They would travel to the mines for year-long periods, contract gonorrhea and tuberculosis there, then return to Yap with the diseases. 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 fertility (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.

3.2 Conclusion

This model suggests that gonorrhea-induced sterility, at levels consistent with Yap in 1930, can reduce the net reproductive ratio by 16 to 22%, which is a conservative estimate given the evidence that 30% of all women in Yap in 1930 were childless. This result is consistent with previous simulation models of infertility and population growth. Reductions at this level have the potential to change the sign of population growth from positive to negative.

[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).

Yap's population was quickly diminishing during the Japanese colonial regime, and infertility from gonorrhea played a significant role. Japanese colonial activities and labor recruitment, along with Yap's unique social and physical environment, contributed to the spread of gonorrhea, thus indirectly affecting native population growth. Additional work is needed to measure the impact of other diseases—specifically tuberculosis—on mortality and population growth, and to explore in further detail the significance of Japanese labor recruitment in disease transmission.

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