NEW ZEALAND ARCHAEOLOGICAL ASSOCIATION NEWSLETTER

GENESIS IN OCEANIA

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Introduction

A myriad of Pacific islands were settled by man in prehistory.
On most newly-settled islands, the founding group were of a number
far less than that ultimately achieved. Moreover, that founding
group had few limitations placed on its initial growth, for the
island's resources usually were of a type well known to the settlers
and not previously exploited by any ecologically equivalent animal.
Finally, population levels were far below those necessary to sustain
many communicable diseases (Cockburn 1971:50) and population density
at a point where inter-person and inter-group stress would be minimised.

Excluding the often fantastic and myth-embedded traditions known to
their descendants, any knowledge of these founding settlements is lost
to us, for their archaeological remains on any island permanently
settled must be trivial. We know that the size of founding groups is
limited by the size of the ocean-going vessels of Oceania. We have
evidence from physical anthropology that founding groups were small
samples of the parent population, and developed into populations in
isolation, for the founder effect, of small settling group missing
even quite frequent genes of their parent population, is often adduced
for Pacific people (Howells 1973:53).

Some authors have speculated on the growth rate of founding populations
in Oceania. New Zealand is a case in point, though it cannot be held
to be an example of settlement by people familiar with the environment.
Groube (1970) and Shawcross (1969) have suggested rates of 1.5% p.a.
were reasonable. Mihaljevic (1973) and both of the above have based
some arguments on the ability of rates of this order to achieve New
Zealand's late population well before the end of New Zealand's pre-
history. Assumption of prolonged steady rates must be questioned however,
as most Oceanic populations must have grown from very small numbers and
small populations cannot show steady growth. Their numbers are simply
too small for there to be any regular progressions.

There is of course little comparative data on these growth rates.
The growth of the joint Bounty mutineers and Tahitian community on
Pitcairn is an oceanic example, although perhaps not entirely free
from benefit from the considerable increase in medical knowledge
of 18th century Europe (Shapiro 1936:241). A 'best-fit' line through
the growth curve of this community gives a growth rate of 3.3% p.a.

Birdsel gives examples of other populations which in isolation have made
rapid growth (1957). The oft-quoted potential of human populations to
double every 20 years stems in part from these but their applicability
to prehistoric societies has been questioned.

To speculate on population numbers after settlement requires some
knowledge of initial population sizes and of likely settlement dates.
How are these settlement dates arrived at?

Archaeologists are often called upon by the public to give a date when
some area of Oceania was settled, and indeed often give the same consider-
ation of archaeological problems. These are usually hedged with "about"
so many years ago, or give a date range. In almost all cases, these are
given without the archaeologist's having ever identified or dated a site
belonging to a settlement period by virtue of imported artefacts. Rather
the date is usually some subjective extrapolation back from the frequency
of early dated sites, coupled with some consideration of the relative
settlement hierarchy of an area as determined by linguistics artefact
typology and similarity groupings. No-one ever seems to have made the
reasoning or logic of this extrapolation explicit but it is clear that
it must be fundamentally linked with population growth.

An occupation which totalled only a few hundred person-years would be
well nigh invisible archaeologically on most of the larger and permanently
settled islands of Oceania. The total prehistoric occupation of New
Zealand, for instance, must be many million person-years, despite its
short settlement. In such circumstances, only an initial occupation
clearly differentiated culturally could be expected to be found.

There is a clear need for greater rigor in this area if quantitative
estimates of population sizes and growths are to be realistically linked
to dated archaeological material. The investigation reported here
involves a simulation of the growth of hypothetical founding populations,
in an attempt to discern the extent to which chance events in small
populations and uncertainty over basic demographic statistics relevant
to growth, limit the certainty which can be achieved in defining initial
population histories, and thereby dependant settlement dates.

A related question, which can be dealt with at the same time is the frequency of failure of founding populations even when placed in an environment favourable to growth. Population failure has often been adduced for the tropical atolls which have archaeological evidence but had no historical population. Their failure must in large part be related to a basically low potential for population support. To some extent the same risk of failure must occur in small populations before they have had time to capitalise on conditions favourable to growth. Sharp suggests Norfolk and Pitcairn Islands as places which have potential to support populations yet while both have archaeological material neither had a historic population.

It is not impossible that populations which failed through reproductive mischance produced the evidence on some historically unoccupied islands, or might be identified on islands which can support only small populations even where they have through a large part of prehistory.

Modelling of Small Societies

Demographic characteristics for modern population are essentially a recent history - what happened after it happened, averaged for the whole population. For a literate population or a population small enough for recent past experience to be common knowledge, past statistics can have some bearing on the extent the population expose themselves to risk of death or deliberately attempt to increase the population. Thus the variation through time of these rates need not be independent of their previous values, that is they may have some degree of serial correlation. The figures which particularly concern us here are those for human mortality and natality.

Well known measures of these are life expectancy at birth, crude death rate (C.D.R.) that, is, annual births per 1,000 population, and crude birth rate (C.B.R. that is, annual births per 1,000 population. While all three are useful generalisations, they lack the specificity necessary for simulation, rather the measures used here are the age specific death rate and the age specific natality rate. The first as used here is the death rate of a people in a specific five year age group (0-5, 5-10, 10-15, etc., years). The figures in total are related to life expectancy at birth (or at any other age) but different patterns of age specific mortality can still give the same figure for life expectancy at birth. The natality rate is the live birth rate to women in specific five year age groups. The summation of these to a particular age is a related statistic which gives the average number of previous live births to women of that age.

Given these two sets of figures, the structure of a large population
as a closed system is determined.   If the age specific death rates
are high, life expectancy is short and for a static population
natality must be high for the women surviving to adulthood to bear
sufficient children.   If the death rates are low, life expectancy
is long and again for a static population, natality must be low.
The age structure of the populations would vary also.

Reversing the argument, a population with a high natality rate in
relation to death rate, will be growing while one where the rates
are balanced will be static.

These statistics relate to the averages of a large number of people.
Here the chosen figures are applied as the most likely figure for
small numbers of people but in accordance with the small numbers, random
variation about the most likely figure is allowed, but without any
serial interrelation.

Studies of burials can give information on both mortality rates and
natality.   Acsadi and Nemeskeri (1970) give figures for many sets
of burials giving the age structures of the populations in the various
cemeteries.   This age structure is not the structure of the living
population but the age at death from which, given adequate numbers,
and assuming static populations, age specific death rates, or life
expectancies can be calculated.   There is some variation in these
figures but overwhelmingly the evidence for this series is for short
life expectancy at birth, almost always less than 30 years.   There
is growing evidence from Polynesia that life expectancy was low.
Figure 1 gives the age structures of some series of burials from Tonga
and Hawaii.

The inevitable corollary of low life expectancy is high fecundity.
Up until the last few centuries the rate of increase of the earth's
population was in modern demographic terms minute.   The evidence
given by Acsadi and Nemeskeri demonstrates the control on many
populations was a high death rate, at all ages.   The causes of the
high death rate were undoubtedly various.   Natality in consequence
must have been generally high, and abstinence, abortion and infanticide
as population controls could only alter a basically high rate.

(A population with a high natality will be better adapted to take
advantage of temporary or long term conditions favourable to population
growth for a population with repressed natality has a less fertile age
structure and a traditional resistance to population increase to over-
come).

It is possible that some traces of child-bearing left on women can
give data on natality (Sutton 1974:67-70), but that so far presented
is too infrequent to be of use.   Rather, the equation above will be
used, because low life expectancy is the norm, the consequent high
fecundity is also the norm.   The figures used have not been observed
in any western society since the Victorians.   They are however figures
observed quite frequently in technologically more backward countries,
particularly in Africa.

The situation in Oceania where many small founding populations were
permitted rapid growth is a rare one in world prehistory.   I have
chosen to model this by assuming high natality was natural and in
conjunction the environment permitted what in prehistoric terms is a
long life expectancy.

The fecundity of fertile women and one table of age specific death
rates are given on Figure 2.   The first is the rate for an African
state with low life expectancy, while the second is a U.N. model life
table giving a life expectancy of 42.9 years.   This is an extremely
long life expectancy for a prehistoric society and three lower rates
have also been used here, taken from Weiss (1973), called here B, C
and D.   These are life tables designated by him tables 35-70, 32.5 -
60 and 25-55 having life expectancies at birth of 36.1, 29.8 and
23.4 years respectively.

Table 1 gives some statistics which result from the application of
these rates to a large population having 7% infertile women.

No differentiation was made between male and female death rates.
These rarely differ greatly.   Female rates are usually a little lower
and to counter this male to female ration at birth of 1 to 1, lower
than usually observed, has been adopted.

The other demographic statistic incorporated into the model is an
allowance for infertility.   Few figures seem to be available for
males, while female statistics are more common.   The causes of child-
lessness among women are several.   In modern societies, choice is
often involved, but in some societies, spinsterhood and early widow-
hood are factors.   Male infertility in the case of married women is
also a factor.   A review of the statistics for a large number of
countries reveals the figures are asymptotic on a lowest frequency of
childless nature women of about 7%.   This figure has been adopted here
though it is possibly a little low.   As the statistic is in part a
function of male infertility the latter has been ignored.   Congenital
infertility or subfertility in males is in all probability very low.
In the absence of mumps and tuberculosis, both formerly absent in the
Pacific, disease-caused male infertility would also be rare.

In making predictions for a large population these sorts of statistics can be applied impersonally treating the population as a breeding machine. This is much less valid for a small population. No individual is a breeding machine and the populations we are considering consist of a very small number of individuals. The only theoretically adequate model of such a population is one which treats people as individuals with social as well as reproductive interactions. This is not attempted here, rather, the model used concentrates almost exclusively on the biological side of population dynamics.

To a social anthropologist, the failure of the model used to limit births where incestuous relationships must be made, or limitations on widows may occur, may seem serious. I would counter by pointing out the circumstances of small colonising groups are exceptional, and not known to us from normal ethnographies. The killing or suicide of widows known to us from many oceanic societies is similarly ignored. Gross imbalances of sexes can occur in small societies. The model used here makes only one concession to adjusting this in that births in any 5 year period are restricted to not more than 5 per adult male. This is an entirely arbitrary estimate and one which presumes polygamy. Childbirth is precluded in the model only if there are no adult males (Ages 17.5 to 57.5 years).

To a demographer, there are several weaknesses. The fertility rates are properly applicable only to large numbers of women. There are two factors included under these statistics; a natural decline in fecundity and conception opportunities for women who are still fertile as they grow older, and a not inconsiderable number of women who become infertile through disease or childbirth. When population numbers are low, it would be more rigorous, (but more difficult) to separate these two. Further, some women can be identified as subfertile, and prone to miscarriages. Ideally, with small populations, these would be identified.

The random nature of the deaths overlooks their frequent episodic and grouping nature. For small populations one can overlook the outbreak of a disease suddenly reducing numbers, for the population numbers are too low to support any such virulent disease. However, multiple deaths from accidents can occur. A pertinent example is drowning resulting from boat mishaps. Small populations well below environmental limits should be little affected by the natural disasters which can affect food supplies in some parts of Oceania - so this can be safely overlooked. The death rate of mothers at childbirth is usually far from negligible in primitive societies and again this only has a blanket coverage rather than a detailed one which would be ideal for a model of a small population.

The number of births, or deaths, or the sex balance of births in a period is not of course absolutely predictable, especially so in small populations. To overcome this, the program used here incorporates randomising procedures whereby the ideal values are varied according to a chosen probability distribution. The births are varied from the expected number by a Poisson distribution, while deaths, the balance of births and the number of infertile females are handled by a binomial distribution. The Poisson probability could on rare occasions give numbers of children per women per five year period which exceeds physiological limits. To halt this, an upper limit of three births per fertile women per five year period has been set. This condition is likely to apply only to the smaller population sizes treated here.

The most difficult problem was to decide on initial populations for the colonising group. In view of several points in the model probably tending to overestimates of the growth, it was decided to make these somewhat ideal. In consequence, all the initial populations are of balanced sexes, all females are considered fertile and almost all females are of childbearing age. The five founding populations used in this study are given in Table 2. The start populations then could be looked on as part of a slightly larger more typical group with the remainder not contributing biologically to the population growth.

Such selected initial populations are not improbable in some circumstances however. Historical accounts of involuntary drift voyages mention canoes which contained parties of young people lost on social visits and the crew of voluntary voyages are more likely to over-represent young people - usually the more adventurous of a community. After long voyages the exigencies of the voyage would select as survivors, people in just the age group used here.

Lastly, geneticists have pointed to minimum populations which they consider to be genetically fit for survival. Their figures, 200 is commonly quoted, are unbelievably high. given what we know of Oceanic prehistory. However, at the lower population levels we are dealing with, disadvantageous genes could become universal. This is not covered by the model.

The model then will represent demographic features of an initially ideal founding population in a benign and familiar environment.

Program Details

The simulation program was written in FORTRAN by the author and
run on the University of Auckland Burroughs B6700 computer as a
routine job.   For modest population numbers this system allows
several growth simulations to be made a second, indicating that
as far as simulation procedures are concerned this is neither
complex, nor its consequence, slow.   A flow diagram for the
program is given in Figure 3.   The time increment in each cycle
is 5 years.

The figures applying to a five year age group are applied to people
who spend most of their time in that group in a five year increment.
For example, the mortality and fecundity rates for women of age
range 20 to 25 are applied to the group graduating from class 17.5
to 22.5 to age class 22.5 to 27.5.   In totalling the population
at the end of each five year period a correction is made for deaths
among the new-born.

In selecting the number of births the program takes a random number
between 0.0 and 1.0 on a square distribution and treats this as a
probability.   Using the ideal number of births, the program then
calculates the Poisson probability of no births, one birth, two births
etc., and successively accumulates the total probability until it
exceeds the randomly selected value.   The number of births at which
this occurs is then taken as the number for the period.   The
potential births to the women were not calculated for the women alive
at the beginning of the 5 year period, rather to the average of the
numbers, at the beginning and at the end.

The procedure with the binomial distribution is similar, with a
random number being generated as a probability, and successive
calculations of the probability for no deaths, one death, two deaths
etc., (or males or infertile females on other callings of the sub-
program) until the accumulated probability exceeds the random
probability.   The random number generator is a Burroughs intrinsic
giving a psuedo random sequence.   Care has to be taken in using the
program to avoid getting the identical sequence in separate runs.

RESULTS AND DISCUSSION

Achieving Growth

The time to achieve a reasonable population size proved to be
very variable.   A figure of 200 people was adopted somewhat
arbitrarily as a population which could maintain steady growth.
A number of simulations were continued until the population exceeded
this figure.   These results are given in Table 3.   Inspection of
these shows that the average time to reach 200 became longer with
smaller initial populations, and with lower life expectancy.
The longer the average time became the greater the range of time
was, that is the variability increased.   The variability,
particularly for Tables B,C and D seemed to fit a logarithmic
transformed normal distribution best and this has been adopted
for these tables.

These figures are plotted graphically on Fig.5.   The form of the
graph is 'log-normal' where compound interest growth plots as a
straight line.   A 95% probability zone has been sketched on these
figures indicating there are 19 chances in 20 a
population growth line would fall.   The 'best fit' growth model
lines superimposed show consistently higher rates than a steady
large population growth (Table 1).   This can probably be attributed
to the optimal initial population's age structures.   Looking at
what must have happened in prehistory, (if possible founding
populations sizes have some uncertainty and there is a similar
uncertainty over growth potential), these figures give us an indication
of the uncertainty associated with the time to achieve growth.   If an
extrapolation is being made from archaeological data back to a settle-
ment date this uncertainty is a fundamental limitation to the accuracy
of my settlement date estimate.

It is unlikely that this method can define a settlement date other than
to a 300 year range.   If archaeologists wish to define settlement
dates to a closer time range than one of 300 years duration they must
do it by methods other than extrapolation of the frequency of post
settlement evidence.

For populations with lower potential growth rates it is possible for
there to be several centuries pass before steady growth is achieved.

Failures

Population simulations looking for failures were terminated if
the population exceeded 40, these runs being counted as successes.
The data generated for failures deliberately concentrated on the
smaller founding populations, as the larger were quickly found to
have good survival records.   As could be expected, failures
dropped rapidly with increasing initial populations and were lower
with longer life expectancies.   Table 4 and Fig.6 show the data on
frequency of failure.   The time to failure was very variable and
became more so with shorter life expectancy.

A few populations failed almost instantly but typically it was
40 to 100 years before failure, with extreme examples surviving
up to 400 years before becoming extinct.   Some of these simulations
still reached quite high populations before later failure.   The
highest reached by a Table A population which subsequently failed
was 16 people.   A Table B and a Table C population both reached
19 people and a Table D population reached 38 and still failed later.

Overall these results suggest small founding populations could have
quite regularly failed but those larger should have had little
difficulty.   There is also the potential here for a few populations
to fail after surviving several centuries, despite conditions
favourable to growth.

Beyond Settlement

Oceanic communities did not continue to grow at rates anywhere near
3% p.a.   Most must have reached some equilibrium position.   Even
when growing we cannot expect populations to hold steady rates for
long periods.

The lowest steady growth rate which could possibly explain the
Maori population is about 0.6% p.a.   Green shows (1973:73) that a
similarly calculated rate for Tonga must be below 0.3% p.a.   The
possible growth rates in these cases cannot overlap.   If we went
further west into earlier settled parts of Oceania even lower overall
rates than for Tonga result.

For New Guinea it is perhaps 0.03%. Green (pers. comm.) in commenting on these figures points out there are no valid grounds for believing the achievable growth rates of past populations have such a geographical restriction. Rather, they strongly suggest that slowing growth rates after settlement are the norm. Such calculations then give us no guide to what the initial growth rate was, though we might expect it was occasionally faster than 0.8% p.a. The latter figure is a "best fit" steady rate growth for New Zealand. Cordy (1974:100) gives similar for Hawaii.

On small islands there are fundamental resource restrictions on populations, restrictions which must make themselves felt soon after settlement. Any political, social or biological influences on mortality or fecundity are universally effective in small populations, leading to fluctuations when approaching or under the control of the limited resources.

Increased mortality rates can be expected to be the most common control - though a simultaneous involuntary decline in fecundity is likely, but never to such low fecundity levels as in modern western societies.

On larger islands and continental land masses, ultimate resource restrictions are initially more remote, but some choice resources may quite quickly become heavily exploited. The potential for further growth by group fission and settlement of under-exploited areas, remains large. It is only when groups become enclosed by competing groups' territories that resource limitations will become very effective.

Political and social effects on mortality and fecundity will exist at a local level almost from settlement but land-mass wide, synchronous fluctuations will only occur with the development of unified political and social systems linking or affecting the bulk of the population. The potential of continental lands for the evolution of new economies and life ways may be sufficient to make the concept of an ultimately static population untenable. Even after settlement group fission may result in the persistence of small Mendelian populations (Sutton 1974:141).

While physical anthropology may well give us good data on the longevity of individuals in group burials, which might be equated to localised populations, this data is not readily convertible into growth rates, or necessarily of general applicability to total populations.

These problems add up to very considerable difficulties for those who wish to put figures on populations.

I remain strongly sceptical of the utility of applying archaeological data to discern changing population sizes, for the precision possible is insufficient.

Figure 6 is an attempt to delimit the zone in which New Zealand's prehistoric population may have fallen, annotated with the basis for the restraints I have adopted. I doubt if it is possible to use archaeological data to narrow the zone more than marginally. The form of graph is again log-normal where steady compound growth rates show as straight lines. The diagram shows clearly that the 1800 AD range of population estimates for New Zealand is a relatively precisely known point when compared with earlier uncertainty. The zone of uncertainty is such that it can subsume almost any model of population expansion. The growth rate from C to D is 0.6% per annum, while that between A and B is 3.1% per annum. The zone can contain for instance, steady growth, or a wide variety of logistic curves with slowing growth. If this is typical, it suggests that at a macro level empirical conformation of any population model is unlikely.

This hopefully may not be the case in studies at more restricted level, but small numbers here are a restraint on certainty.

Modelling related to population is somewhat of a vogue in recent literature (with some authors treating the expansion of band societies into continents (Martin 1973) and large islands (Yengoyan 1967) while others deal with more static problems of group interaction (Birdsel 1973). This investigation and that of Wobst (1974) suggest variability in small groups cannot be excluded from such studies and on inclusion can lead to new knowledge of population system limitations.

ACKNOWLEDGEMENTS

TABLE 1

Large Population Statistics

Longevity (independent of fertility)

Life Table	UN		Weiss	
	A	B	C	D
Life expectancy at birth, years	42.9	36.1	29.8	23.4
Expectancy aged 20 years	-	33.2	30.9	23.9
Sub-adult ($<$ 20 years) deaths, %	31	36.3	46.1	53.1
Growing Population Statistics				
CBR (per 1000)	51.3	49.7	51.2	52.4
CDR (per 1000)	19.1	23.7	32.3	41.2
Growth rate, % p.a.	3.22	2.60	1.89	1.12
Doubling period years	21.9	27.0	37.1	62.3
Population structure % in age groups				
0 - 17.5 years	53.9	55.7	53.4	54.6
17.5 - 37.5	29.5	28.8	29.3	30.0
37.5 - 57.5	12.5	11.6	12.7	11.9
57.5 -	4.1	3.9	4.6	3.5

TABLE 2

Initial Populations

Pop. No.	1	2	3	4	5
Age Range	M.F.	M.F.	M.F.	M.F.	M.F.
2.5 - 7.5					1 1
7.5 - 12.5				1 1	1 1
12.5 - 17.5			1 1	1 1	2 2
17.5 - 22.5	1 1	1 1	1 1	2 2	4 4
22.5 - 27.5		1 1	1 1	2 2	4 4
27.5 - 32.5			1 1	1 1	2 2
32.5 - 37.5				1 1	1 1
37.5 - 42.5					1 1
TOTAL	2	4	8	16	32

TABLE 3

Time to Reach 200 People, Years.

Life Table	A	B	C	D
Pop. No.				
1 (2 people)	130 + 30 (n = 17)	-	-	-
2 (4)	118 + 17 (29)	136+28-23 (18)	118+37-31 (10)	-
3 (8)	96 + 17 (20)	-	-	252+94-66 (10)
4 (16)	70 + 10 (20)	87+18-15 (28)	127+42-32 (20)	224+89-66 (19)
5 (32)	48 + 5 (20)	-	-	-

TABLE 4

Failure Frequency, Percentage

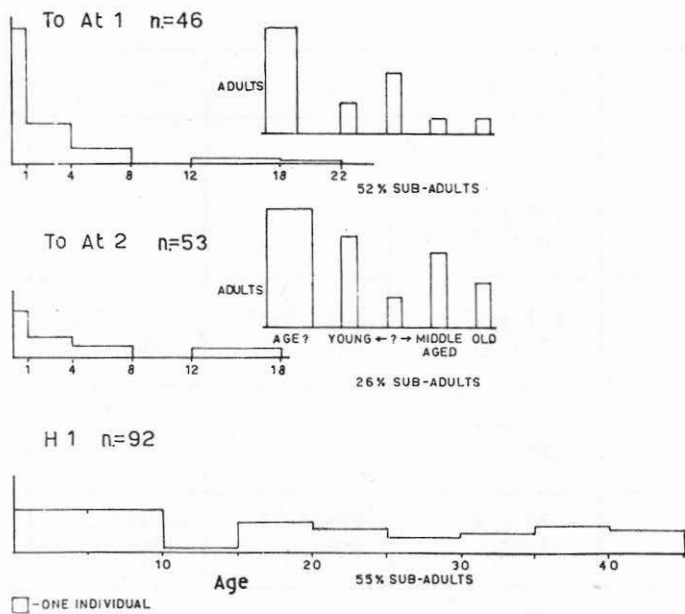| Life Table	A	B	C	D
Pop. No.				
1 (2 people)	34% (n=99)	54% (80)	72% (100)	95% (100)
2 (4)	4% (110)	16% (100)	41% (120)	71% (100)
3 (8)	0% (80)	2% (80)	7% (100)	44% (120)
4 (16)	0% (20)	0% (28)	0% (20)	5% (20)

Fig. 1   Age at death of three series of Polynesian burials
          To-At-1 and To-At-2.   Tonga Tapu (*Pietrusewsky 1969:359,
          Davidson 1969*), Hl, Pu Alii Sand Dune Site, South Point,
          Hawaii Island, Hawaii (*Underwood 1969*).
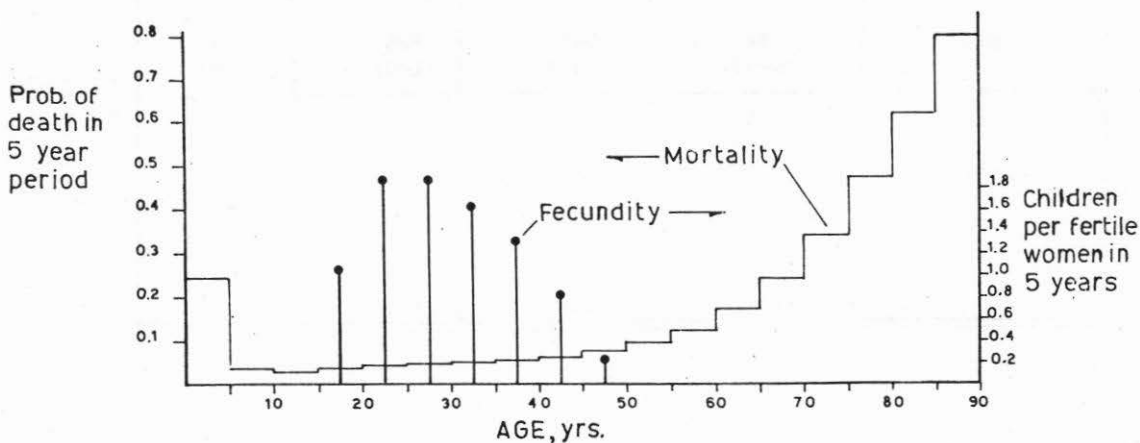
Fig. 2   Mortality and Fecundity patterns used in the simulation
          model.

M. :MALE, F. :FEMALE, I.F. :INFERTILE FEMALES
(B) :BINOMIAL PROBABILITY SUBPROGRAM CALLED
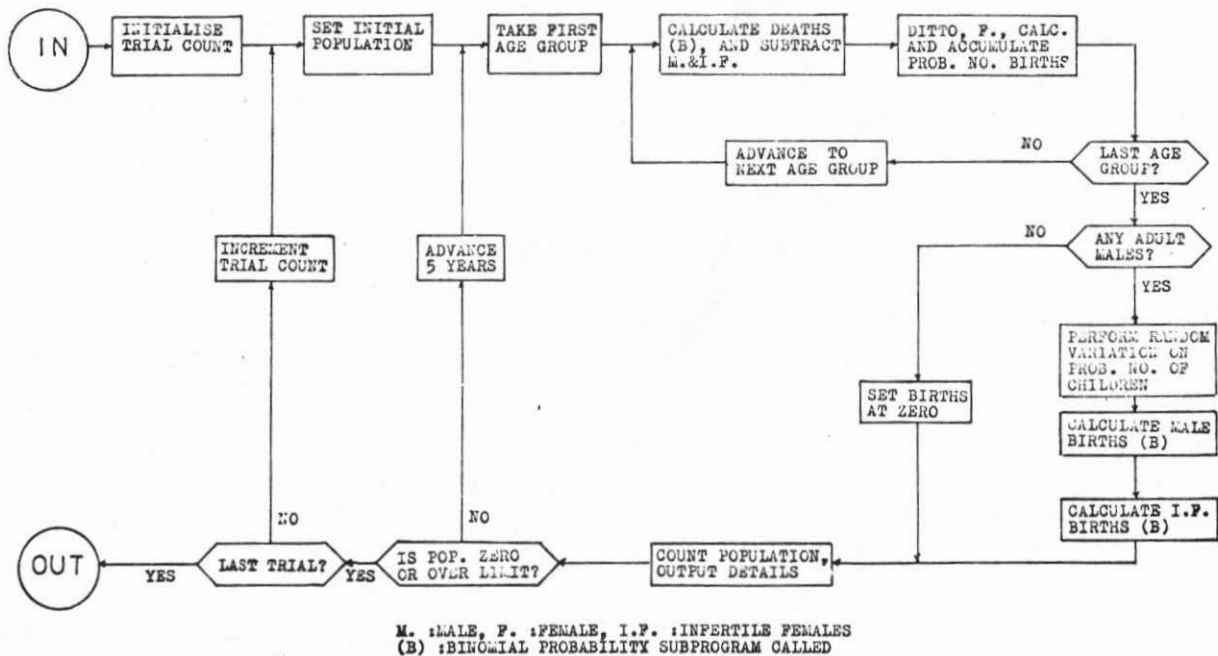
Fig. 3   Flow diagram for the simulation program.
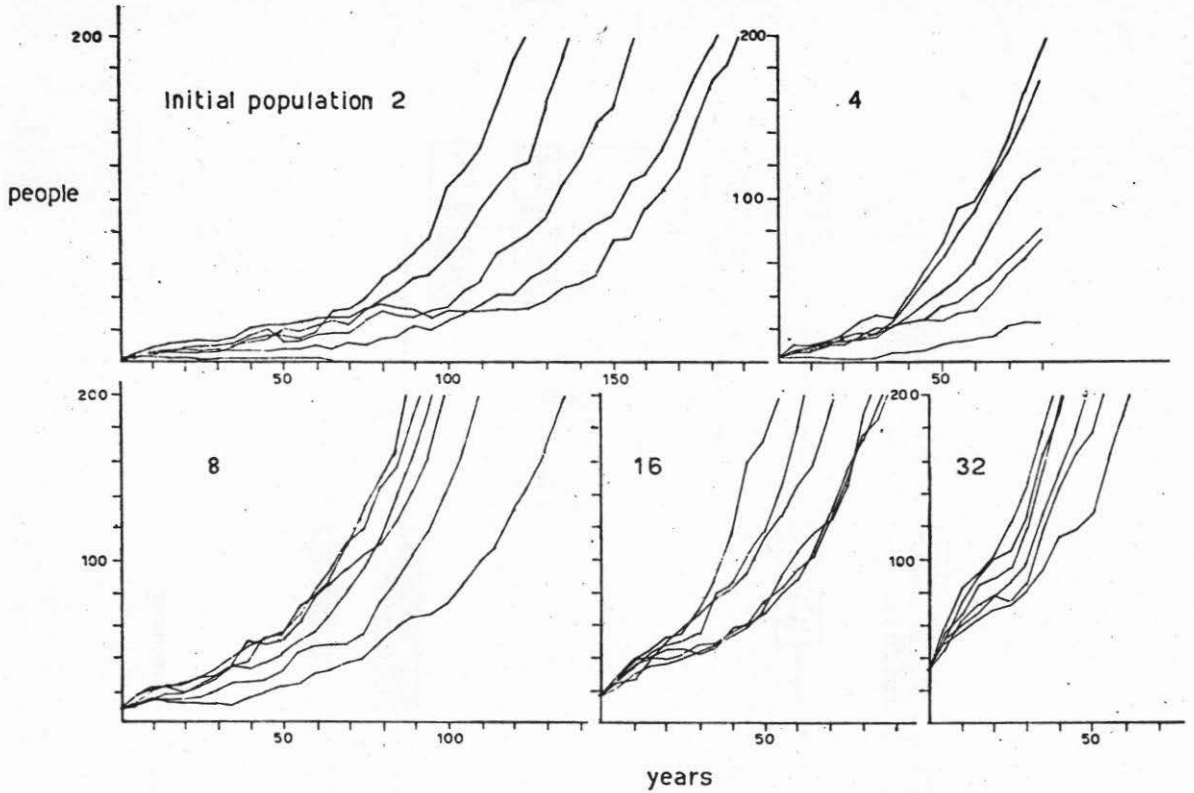
Fig. 4   Illustrative population growth curves, six selected at random for each initial population.   Life Table A.

Fig. 6   Failure frequency.

Fig. 5   Diagram illustrating the confidence limits in extrapolating
back to an initial population from a population of 200
people.   The limits are sketched in to fit the standard
deviation bars.   Note that exponential growth curves on
this semi-log. plot are straight lines.

Fig. 7   Likely zone within which New Zealand's population history
          has fallen.

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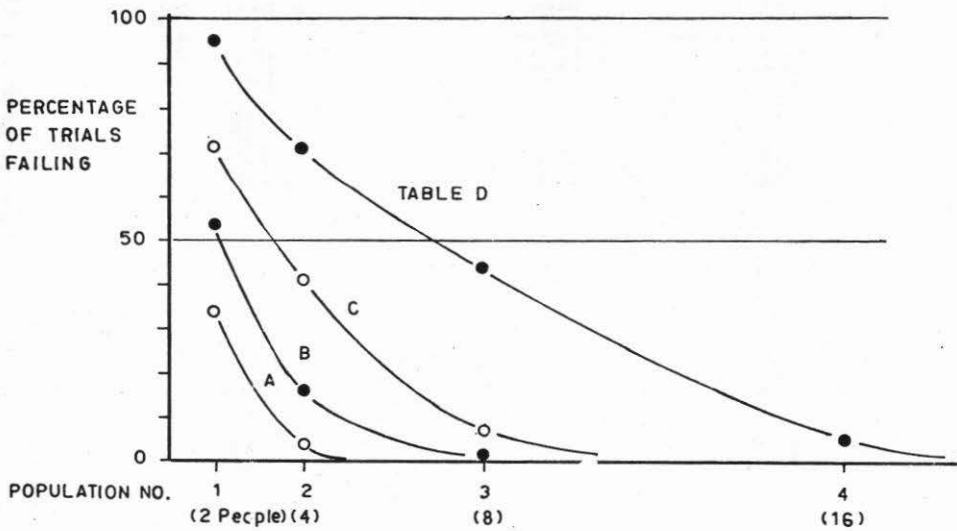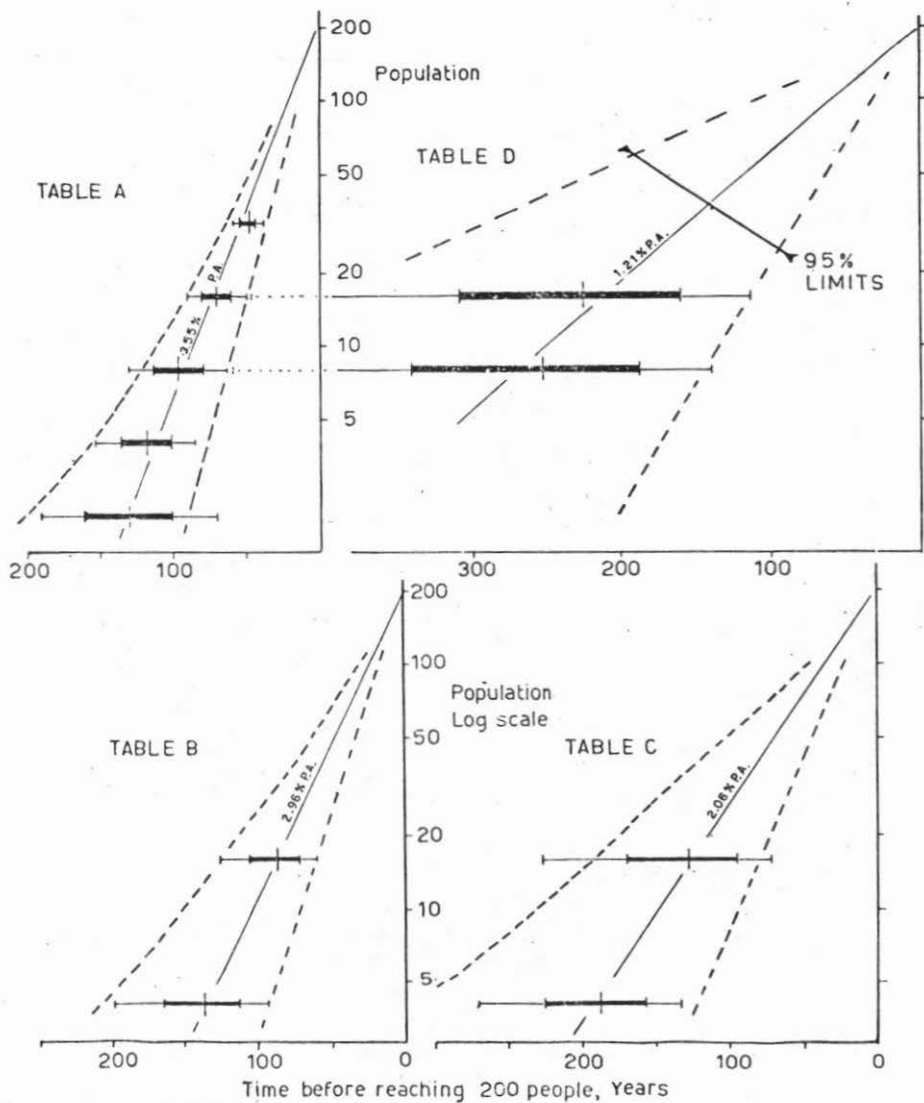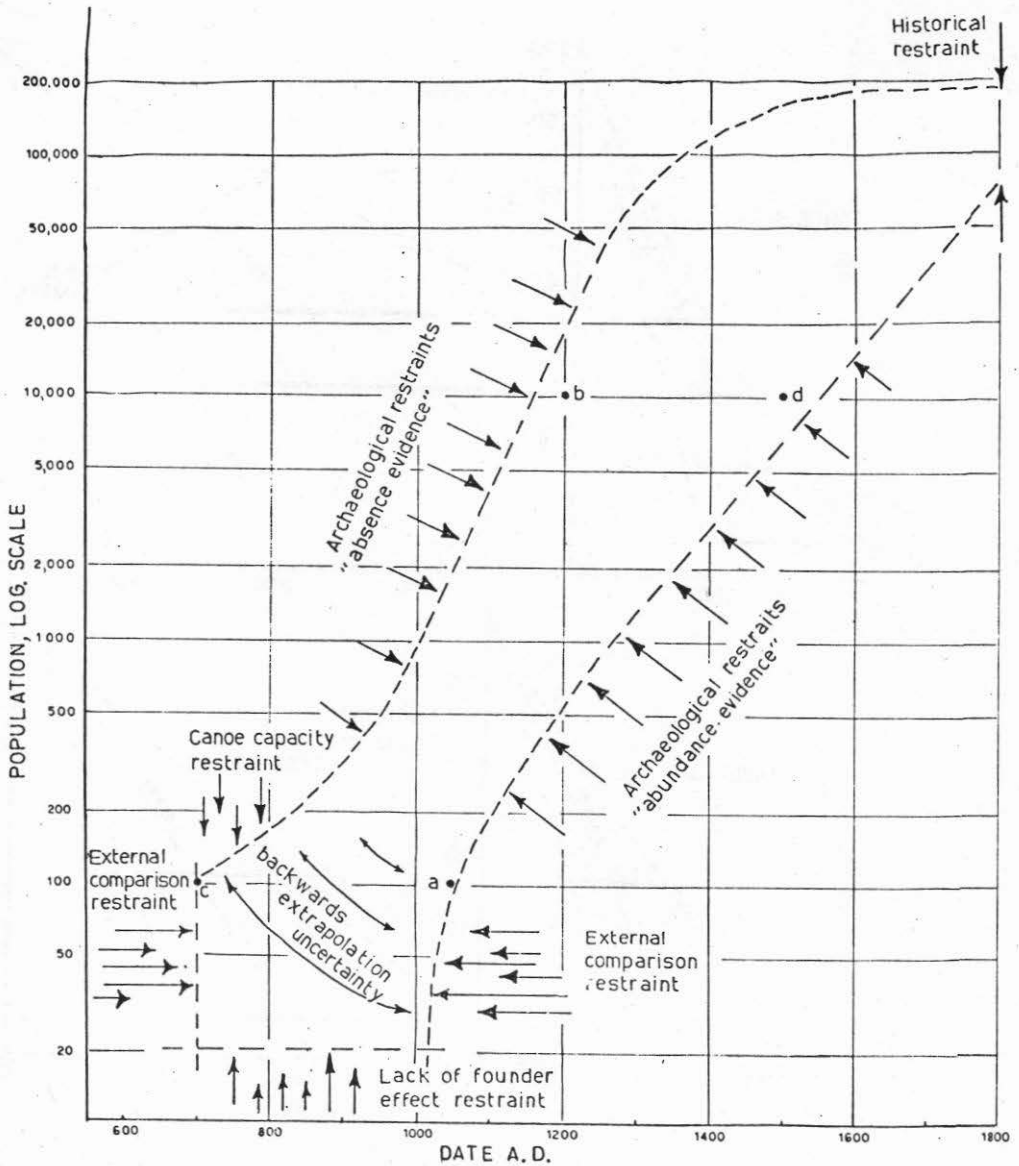   Akademiai Kiado, Budapest.

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