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Culture and Biological Adaptation

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THE results of one phase of a recently completed study which are pertinent to the question of the biological adaptiveness of culture are presented here. For the purpose of interpreting the genetic characteristics of Pacific Island peoples, research was initially directed to the problem of identifying the determinants of size, structure and dynamics of Micronesian island populations. I have relied extensively on concepts discussed at length by Simpson (1953, 1963) in testing the proposal that culture is biological adaptation, as measured by the criterion of relative abundance of organisms. This operational standard, extensively used in ecological studies, is accepted merely as an objective, available index appropriate to this study.

I believe this study indicates that the complex of socially transmitted beliefs and associated behavior constituting a system of social stratification is biologically maladaptive, resulting in the decreased relative abundance of the human population in which such phenomena receive social expression. A greater sophistication is required on the part of anthropologists *and* biologists who seek to comprehend the nexus between those realms or orders of phenomena which are designated "Culture" and "Biology."

POPULATION AND ENVIRONMENT IN MICRONESIA

Micronesia is a term applied to the geographical region of the Pacific Ocean described, very generally, as extending from a few degrees south of the equator to about 20° north latitude, and from about 180° to 130° east longitude. Some 2400 land units have been reported for this area (Bryan, in discussion of Thomas 1963), of which slightly over 2100 are considered to constitute 112 islands or atolls. These islands and atolls comprise four island groups—the Mariana, Caroline, Marshall, and Gilbert Island groups—plus two independent land forms, Nauru and Ocean Islands.

The Contact and post-Contact history of the region has been reviewed extensively elsewhere (Burney 1803–1817; Bradley 1937; Beers 1944; Christian 1899a, 1899b; Grimble 1933–1934, 1943, 1952; Oliver 1961; Thompson 1947; Wallis 1953; *et al*), but the current division of the region among foreign administrative powers may be summarized here. Three of the island groups—the Marshall Islands, the Caroline Islands and the Mariana Islands, excluding Guam—form the United States Trust Territory of the Pacific Islands, a United Nations trusteeship to the United States, dating from 1947. Formerly, these island groups were held as a League of Nations mandate by Japan during the period between the two World Wars. Guam, now an unincorporated United States Territory, was obtained from Spain by the Treaty of Paris in 1898. The Gilbert Islands, including Ocean Island, are today part of the British Gilbert and Ellice Islands Colony, with Colony status replacing an earlier British Protectorate in 1916. Finally, Nauru Island, which has successively moved from German hands to a League of Nations Mandate under Australian administration, is presently a United Nations Trust Territory, administered by Australia. Earlier foreign influences in the Micronesian region include those of Spanish derivation (until 1898) and, until about 1914, of German origin.

Anthropological research in Micronesia has been limited, despite post-World War II studies included in the United States Commercial Company (USCC) Economic Surveys and the Coordinated Investigations of Micronesian Anthropology (CIMA) reports. Consequently, much of the present controversy as to the cultural, as also physical characterizations of the Micronesians derives from lack of information. Oliver (1961), Murdock (1948), Matsumura (1918), and others disagree as to the number of culture "areas" or "sub-areas" presented; Hunt (1950), Hasebe (1928), Matsumura (1918), *inter alia,* dispute the racial or sub-racial classifications to be applied. Linguistic studies (Grace 1955, 1959; Capell 1962) have also been handicapped by limited and incomplete data. At the gross level of comparison to other Pacific geographical-cultural regions, the available materials do indicate that a single cultural tradition (including, however, much local variation) is represented on Micronesian islands and atolls, with the exceptions of Kapingamarangi and Nukuoro Atolls in the Caroline Islands group. The latter two atolls support populations showing marked Polynesian affinities in cultural, linguistic, and biological attributes (Emory 1948; Wiens 1956).

As a result of foreign interest and administrative responsibilities in the Micronesian area, a body of data pertaining to topics of interest to the determination of population characteristics of Micronesian peoples is available in the journals, records and reports of travelers, administrators, alien residents and scientists on the Micronesian islands and atolls. Moreover, conditions attached to trusteeship and mandate assignments have resulted in an availability of census and demographic records submitted to international organizations.

Information as to physical, biotic and cultural features of the Micronesian environment has been summarized and census data for Micronesian populations collated and recorded (Hainline 1964). In view of the incompleteness and questionable reliability of earlier reports, census data reported from the latter part of the period of Japanese control in the area (ca 1935) and from the period of United States trusteeship have been exclusively employed in statistical analyses reported herein. The accuracy of the census reports of this derivation has been questioned (Mason 1952; Weins 1956), indicating the probable greater unreliability of earlier reports and further justifying this limitation.

As Simpson (1953) points out, the concept of adaptation necessitates a recognition that it is an environment to which adaptation is made. Somewhat parallel to Simpson's four levels of environment, a study in human ecology recognizes: 1) the physical environment; 2) the biotic environment; 3) the cultural environment; and 4) the individual human biological or physiological environ-

TABLE 1. LAND AREA, LAGOON AREA, POPULATION AND POPULATION DENSITY OF MICRONESIAN ISLANDS AND ATOLLS*

Islands and Atolls	Island Group	Land Area, in square miles	Lagoon area, square miles	Population (date of census)	Population (date of census)	Population Density—Time I	Population Density—Time II
West Fayu Atoll	Caroline	0.024	2.178	0 (1935)	0 (1948)	0	0
Pikelot Island	Caroline	0.036	—	0 (1935)	0 (1948)	0	0
Gaferut Island	Caroline	0.043	—	0 (1935)	0 (1948)	0	0
Jemo Island	Marshall	0.060	—	0 (1935)	0 (1948)	0	0
Olimarao Atoll	Caroline	0.085	2.419	0 (1935)	0 (1948)	0	0
Eauripik Atoll	Caroline	0.091	2.286	110 (1935)	125 (1948)	1,209	1,374
East Fayu Island	Caroline	0.144	—	0 (1935)	0 (1948)	0	0
Faraulap Atoll	Caroline	0.163	0.902	291 (1935)	115 (1948)	1,785	706
Ngulu Atoll	Caroline	0.165	147.707	66 (1935)	45 (1948)	400	270
Jabwot Island	Marshall	0.170	—	48 (1930)	0 (1948)	282	0
Bikar Atoll	Marshall	0.190	14.440	0 (1935)	0 (1948)	0	0
Oroluk Atoll	Caroline	0.192	162.348	4 (1935)	0 (1948)	21	0
Elato Atoll	Caroline	0.203	2.888	71 (1935)	36 (1948)	350	177
Taka Atoll	Marshall	0.220	35.960	0 (1935)	0 (1948)	0	0
Tobi Island	Caroline	0.228	—	171 (1935)	141 (1948)	750	618
Nama Island	Caroline	0.289	—	406 (1935)	503 (1948)	1,405	1,740
Kili Island	Marshall	0.300	—	26 (1935)	184 (1948)	87	613
Pulo Anna Island	Caroline	0.313	—	19 (1935)	18 (1948)	61	58
Namoluk Atoll	Caroline	0.322	2.972	294 (1935)	226 (1948)	913	702
Merir Island	Caroline	0.349	—	171 (1935)	18 (1948)	490	52
Farallon de Medinilla Island	Mariana	0.350	—	0 (1935)	0 (1949)	0	0
Lib Island	Marshall	0.360	—	68 (1935)	84 (1948)	189	233
Sorol Atoll	Caroline	0.361	2.740	12 (1937)	10 (1948)	33	28
Lamotrek Atoll	Caroline	0.379	12.166	192 (1935)	134 (1948)	507	354
Pulap Atoll	Caroline	0.383	12.093	257 (1935)	261 (1948)	671	681
Losap Atoll	Caroline	0.396	10.577	570 (1933)	682 (1948)	1,439	1,722
Pakin Atoll	Caroline	0.421	5.523	0 (1935)	0 (1948)	0	0
Mokil Atoll	Caroline	0.478	2.608	258 (1935)	449 (1948)	540	938
Murilo Atoll	Caroline	0.497	135.082	339 (1935)	279 (1948)	682	561
Satawal Island	Caroline	0.505	—	287 (1935)	216 (1948)	568	428
Kapingamarangi Atoll	Caroline	0.521	22.010	399 (1935)	511 (1948)	766	981
Ifalik Atoll	Caroline	0.569	0.939	288 (1935)	214 (1948)	506	376
Erikub Atoll	Marshall	0.590	88.920	0 (1935)	0 (1948)	0	0
Nukuoro Atoll	Caroline	0.644	10.520	198 (1937)	210 (1948)	307	326
Rongerik Atoll	Marshall	0.650	55.380	6 (1935)	0 (1948)	9	0
Ujelang Atoll	Marshall	0.670	25.470	40 (1935)	142 (1948)	60	212
Ngatik Atoll	Caroline	0.674	30.342	295 (1935)	383 (1948)	438	568
Pingelap Atoll	Caroline	0.676	0.465	694 (1935)	685 (1948)	1,027	1,013
Nomwin Atoll	Caroline	0.716	112.573	106 (1935)	134 (1948)	148	187
Ant Atoll	Caroline	0.718	28.700	40 (1933)	30 (1946)	56	42
Mejit Island	Marshall	0.720	—	324 (1935)	299 (1948)	450	415
Etal Atoll	Caroline	0.731	6.252	255 (1935)	244 (1948)	349	334
Sonsorol Island	Caroline	0.735	—	153 (1935)	122 (1948)	208	166
Helen Reef Atoll	Caroline	0.761	39.078	0 (1935)	0 (1948)	0	0
Lae Atoll	Marshall	0.780	6.820	88 (1935)	138 (1948)	113	177
Uracas Island	Mariana	0.790	—	0 (1935)	0 (1947)	0	0
Maug Island	Mariana	0.822	—	0 (1935)	0 (1947)	0	0
Utirik Atoll	Marshall	0.940	22.290	126 (1935)	166 (1948)	134	177
Ujae Atoll	Marshall	0.990	71.790	160 (1935)	244 (1948)	162	246
Namorik Atoll	Marshall	1.070	3.250	368 (1935)	461 (1948)	344	431
Ailinginae Atoll	Marshall	1.080	40.910	0 (1935)	0 (1948)	0	0
Pulusuk Island	Caroline	1.083	—	194 (1935)	202 (1948)	179	187
Fais Island	Caroline	1.083	—	334 (1935)	250 (1948)	308	231
Lukunor Atoll	Caroline	1.090	21.246	888 (1935)	788 (1948)	815	723
Taongi Atoll	Marshall	1.250	30.130	0 (1935)	0 (1948)	0	0
Puluwat Atoll	Caroline	1.313	0.600	335 (1935)	269 (1948)	255	205
Ebon Atoll	Marshall	1.520	40.090	648 (1935)	747 (1948)	426	492
Guguan Island	Mariana	1.615	—	0 (1935)	0 (1947)	0	0
Namonuito Atoll	Caroline	1.710	723.900	304 (1935)	392 (1949)	178	229
Woleai Atoll	Caroline	1.749	11.354	570 (1935)	354 (1948)	326	202
Satawan Atoll	Caroline	1.757	147.524	1,057 (1935)	1,262 (1948)	602	718

TABLE 1 (*Continued*)

Islands and Atolls	Island Group	Land Area, in square miles	Lagoon area, square miles	Population (date of census)	Population (date of census)	Population Density—Time I	Population Density—Time II
Ulithi Atoll	Caroline	1.799	209.560	408 (1937)	402 (1948)	227	223
Wotho Atoll	Caroline	1.830	36.650	47 (1935)	31 (1948)	26	17
Sarigan Island	Mariana	1.930	—	0 (1935)	0 (1947)	0	0
Tamana Island	Gilbert	2.000	—	1,110 (1936)	883 (1947)	555	442
Ailuk Atoll	Marshall	2.070	68.470	293 (1935)	319 (1948)	142	154
Bikini Atoll	Marshall	2.160	229.400	159 (1935)	0 (1948)	74	0
Aur Atoll	Marshall	2.170	92.580	279 (1935)	418 (1948)	129	193
Ocean Island	"Gilbert"	2.300	—	1,898 (1936)	1,809 (1947)	825	787
Namu Atoll	Marshall	2.420	153.530	276 (1935)	341 (1948)	114	141
Eniwetok Atoll	Marshall	2.670	387.990	81 (1935)	0 (1948)	30	0
Aguijan Island	Mariana	2.770	—	0 (1935)	0 (1949)	0	0
Little Makin Island	Gilbert	2.800	—	746 (1936)	965 (1947)	267	345
Asuncion Island	Mariana	2.812	—	0 (1935)	0 (1947)	0	0
Rongelap Atoll	Marshall	3.110	387.770	160 (1935)	95 (1948)	51	31
Majuro Atoll	Marshall	3.140	113.920	782 (1935)	1,473 (1948)	249	469
Wotje Atoll	Marshall	3.160	241.060	590 (1935)	328 (1948)	187	104
Maloelap Atoll	Marshall	3.790	375.570	460 (1935)	457 (1948)	121	121
Marakai Atoll	Gilbert	3.940	7.570	1,684 (1937)	1,797 (1947)	427	456
Likiep Atoll	Marshall	3.960	163.710	495 (1935)	682 (1949)	125	172
Alamagan Island	Mariana	4.352	—	20 (1935)	153 (1948)	5	35
Jaluit Atoll	Marshall	4.380	266.310	1,989 (1935)	960 (1948)	454	219
Butaritari Atoll	Gilbert	4.500	103.680	1,623 (1936)	1,821 (1947)	360	405
Ailinglapalap Atoll	Marshall	4.500	289.690	682 (1935)	705 (1948)	152	157
Kuria Island	Gilbert	4.980	—	261 (1936)	313 (1947)	52	63
Arno Atoll	Marshall	5.000	130.770	942 (1935)	1,071 (1948)	188	214
Arorai Island	Gilbert	5.000	—	1,507 (1936)	1,555 (1947)	301	311
Onotoa Atoll	Gilbert	5.210	21.000	1,605 (1936)	1,490 (1947)	308	286
Kwajalein Atoll	Marshall	5.790	839.300	1,079 (1935)	1,043 (1948)	186	180
Aranuka Atoll	Gilbert	5.970	9.210	288 (1936)	366 (1947)	48	61
Apamama Atoll	Gilbert	6.570	51.120	835 (1937)	1,171 (1947)	127	178
Nikunau Island	Gilbert	7.000	—	1,726 (1937)	1,591 (1947)	252	227
Tarawa Atoll	Gilbert	7.730	132.670	2,620 (1937)	3,529 (1947)	339	457
Peru Atoll	Gilbert	8.150	15.000	2,454 (1937)	2,225 (1947)	301	273
Nauru Atoll	—	8.220	—	1,651 (1936)	1,545 (1948)	201	188
Mili Atoll	Marshall	8.510	294.700	515 (1935)	279 (1948)	61	33
Nonouti Atoll	Gilbert	9.830	143.000	2,080 (1936)	2,000 (1947)	212	203
Maiana Atoll	Gilbert	10.390	63.570	1,410 (1937)	1,422 (1947)	136	137
Apaiang Atoll	Gilbert	11.050	89.780	2,406 (1936)	2,803 (1947)	218	254
Anatahan Island	Mariana	12.480	—	37 (1935)	0 (1947)	3	0
Agrihan Island	Mariana	18.290	—	86 (1935)	124 (1948)	5	7
Pagan Island	Mariana	18.650	—	131 (1935)	0 (1947)	7	0
Tapitivea Atoll	Gilbert	19.000	141.000	3,851 (1937)	3,778 (1947)	203	199
Rota Island	Mariana	32.900	—	764 (1935)	655 (1948)	23	20
Truk Islands	Caroline	37.192	—	10,344 (1935)	9,510 (1948)	278	256
Yap Island	Caroline	38.670	—	3,479 (1935)	2,744 (1948)	90	71
Tinian Island	Mariana	39.290	—	25 (1935)	292 (1948)	1	7
Kusaie Islands	Caroline	42.316	—	1,189 (1935)	1,652 (1948)	28	39
Saipan Island	Mariana	47.460	—	3,282 (1935)	4,945 (1948)	69	104
Ponape Islands	Caroline	129.040	—	5,601 (1935)	5,735 (1948)	43	44
Palau Islands	Caroline	188.269	—	5,747 (1937)	5,900 (1948)	31	31
Guam Island	Mariana	215.500	—	16,402 (1936)	24,139 (1947)	76	112
Totals:		1,054.763	7,154.022	97,665	107,289	28,855	28,319

Summary: N = 112
Volcanic Islands = 20
Coral Atolls and Islands = 92
Drought = 15
Non-drought = 77

NOTE: Ocean Island, although a member of the Gilbert and Ellice Islands Colony for administrative purposes, should be considered as an independent island rather than a member of an "island group," and thus has been marked as "Gilbert Island Group."

* See Hainline (*op. cit.*) for full listing of population and area data. Above data from Bryan (1946a, 1946b), Mason (1951), Daniel (1943), Robson (1944), Bowers (1951), United States Department of Navy (1944, *et seqq.*).

ment. Practically, moreover, it is necessary to recognize some limitations on the ecologist's powers of observation, identification, and analysis. One attempts to identify from the "total environment" those environmental features which affect the number and distribution of the members of a population, thus describing the "effective environment."[2] In the case of human ecological studies, particularly, one may also wish to acknowledge what Rappaport (1963) calls the "cognized environment."

Population size data for the time periods specified, and land area and lagoon area measurements for 112 Micronesian islands and atolls have been recorded (Table 1). No effort was made initially to discover what limiting environmental features are subsumed under the latter categories; instead, it is assumed that for these peoples, with a horticultural-fishing economy, some unspecified number of interacting affective environmental features are expressed in the two environmental categories of land area and lagoon area. Further, the assumption was made initially that no affective differences exist in the physical, biotic, or cultural environments on these islands and atolls, nor in the biological environment of the populations of these islands and atolls.

Beginning with these assumptions, statistical analysis is employed to identify the existence of correlations between environment, as expressed in areal measurements, and population size, a criterion of biological adaptation. Subsequently, simplifying assumptions are progressively removed and further statistical tests applied in an effort to identify more precisely the limiting factors of the environment. The specified environmental features which can be tested as possible affective variables of adaptation are selected for consideration largely on the basis of available information.

STATISTICAL ANALYSES OF MICRONESIAN DATA

Following recommended procedure, a scattergram of the data for "All Micronesian islands and atolls" was prepared (Figure 1). The results were, obviously, inconclusive and were not substantially improved when the data was plotted on logarithmic-scale paper. Consequently, the simpler, linear form of regression analysis was selected for use in statistical treatment of the materials.[3]

As Dr. Morris Garber kindly pointed out to me, linear regression analysis involves certain assumptions as to the population from which the sampled data is drawn. Application of the regression formula commonly found in statistics texts to the Micronesian data employed an inappropriate model of the population. The suitable model to use in the present case is not this "Model I," but what Snedecor (1956) has called "Model IA." The critical distinction between the two models concerns the relationship of the standard deviation of X; i.e., where the standard deviation is directly proportional to X, Model IA is properly employed. Following Table 2, which records the results of all statistical tests applied incorporating the Snedecor Model IA, is Table 3, in which the necessary data are presented to substantiate the selection of the population model used here. The results of linear regression (Model I) and also rank correlation

(Spearman) tests applied to this same material are available elsewhere (Hainline 1964).

After identifying a high and statistically significant correlation coefficient of association between land area (X_1) and population (Y_1, Y_2) variables for "All Micronesian islands and atolls", additional tests of correlation were performed. Simplifying operational assumptions were examined by testing the associations

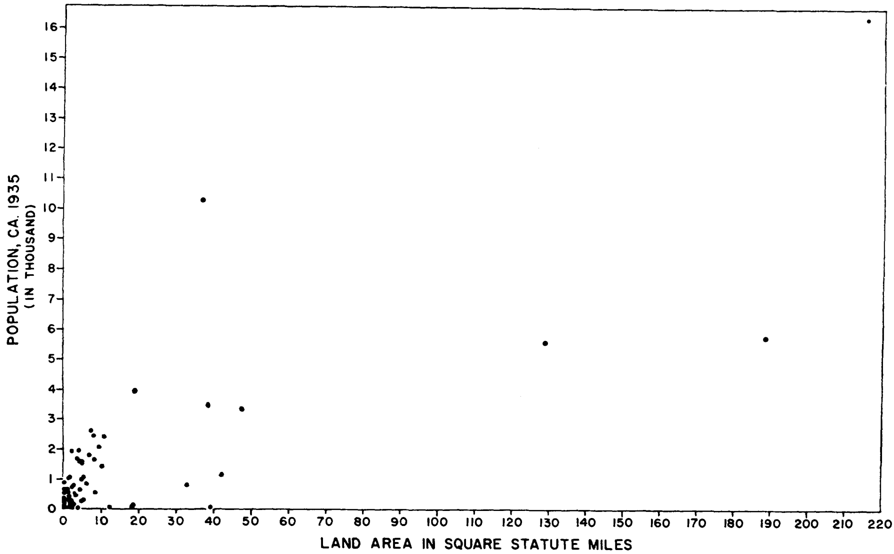

FIG. 1. Scattergram of land area and population, ca. 1935—all Micronesian islands and atolls (N = 112).

between population and certain other variables (X_2, or lagoon area; X_3 and X_4, referring to altitude of volcanic islands) and by restricting the group of items for which association of variables was tested (e.g., coral atolls, volcanic islands, etc.).

A summary and brief comments on the results of these attempts to identify selected affective components of tested environmental variables are presented below.

1. Composition. Significant differences exist in the measure of association of variables for islands grouped as "volcanic" or "coral." This finding is incorporated into subsequent tests.

These differences in geological origin and composition are accompanied by distinctions in such physical features as water resources and soil composition (Piper 1946; Stone 1953), and these, in turn, influence biotic characteristics (Fosberg 1949, 1953; Gantt 1946; Marshall 1951, 1957; Usinger and La Rivers 1953; *et al*). Insularity and geographical proximity define "one *certain* or *given* environment" (Simpson 1953) for Micronesian islands and atolls and comprehend distinguishable, contrasting ranges of variability detectable at more refined levels of analysis.

2. Altitude. Tests were made of association between population variables

TABLE 2. RESULTS OF LINEAR REGRESSION TESTS, MODEL I-A: CORRELATION OF POPULATION SIZE AND SELECTED ENVIRONMENTAL CHARACTERISTICS

All Micronesian Islands and Atolls					
$X_1:Y_1$	112	257.60191	31.156494	8.27**	0.62
$X_1:Y_2$	112	252.87091	31.180025	8.11**	0.61
All Coral Atolls and Islands					
$X_1:Y_1$	92	306.44446	35.850928	8.55**	0.67
$X_1:Y_2$	92	299.94113	36.035013	8.32**	0.65
All Volcanic Islands					
$X_1:Y_1$	20	32.92642	14.380679	2.29*	0.44
$X_1:Y_2$	20	36.348220	13.918197	2.61*	0.51
Coral Atolls and Islands, Non-drought					
$X_1:Y_1$	77	311.01248	41.845511	7.43**	0.65
$X_1:Y_2$	77	299.57348	41.659325	7.19**	0.64
Coral Atolls and Islands, Drought					
$X_1:Y_1$	15	282.99564	48.963741	5.78**	0.84
$X_1:Y_2$	15	301.82872	58.351316	5.17**	0.81
Coral Atolls, All					
$X_2:Y_1$	69	59.041379	23.672656	2.49*	0.29
$X_2:Y_2$	69	54.713595	22.575485	2.42*	0.28
Coral Atolls, Non-drought					
$X_2:Y_1$	58	59.225046	27.936887	2.12*	0.27
$X_2:Y_2$	58	53.650610	26.614662	2.02*	0.26
Coral Atolls, Drought					
$X_2:Y_1$	11	58.073005	21.133156	2.75*	0.66
$X_2:Y_2$	11	60.318461	21.128622	2.86*	0.67
Volcanic Islands, All					
$X_3:Y_1$	20	1.9439769	0.78584225	2.47*	0.31
$X_3:Y_2$	20	2.2412807	0.99355465	2.26*	0.46
Volcanic Islands, "Simple"					
$X_3:Y_1$	10	0.073118044	0.060264072	1.22	0.36
$X_3:Y_2$	10	0.095207696	0.084176493	1.13	0.35
Volcanic Islands, "Complex"					
$X_3:Y_1$	10	3.8148359	1.3512921	2.82*	0.69
$X_3:Y_2$	10	4.3873538	1.7712739	2.42*	0.63
Volcanic Islands, All					
$X_4:Y_1$	20	13,360.434	7,684.8474	1.74	0.37
$X_4:Y_2$	20	16,731.595	10,578.662	1.58	0.34
Volcanic Islands, "Simple"					
$X_4:Y_1$	10	147.27945	135.66090	1.09	0.34
$X_4:Y_2$	10	195.10621	189.34405	1.03	0.32
Volcanic Islands, "Complex"					
$X_4:Y_1$	10	26,573.588	14,509.847	1.83	0.52
$X_4:Y_2$	10	33,268.085	20,290.320	1.64	0.48

Definition of Terms used in Table 2 and following tables:

X_1 = land area, square statute miles

X_2 = lagoon area, square statute miles

X_3 = maximum elevation, in feet, of volcanic islands

X_4 = altitude area index, volcanic islands, $\frac{\text{maximum elevation} \times 100}{\text{area}}$

Y_1 = population, ca. 1935

Y_2 = population, ca. 1948

* = statistically significant at 0.05 level.

** = statistically significant at 0.01 level.

Mathematical formulae, sample regression coefficient Model I-A: $= Y_c = bX$, where

$$b = \frac{\Sigma(Y/X)}{N} \text{ and } t = \frac{b}{S_b}, \text{ with r, calculated from t, } = \sqrt{\frac{t^2}{(N-1)+t^2}}$$

and altitudinal variables X_3 (maximum elevation) and X_4 (altitude-area index) for "all volcanic islands"; for the "simple volcanic island" of Kusaie and the Northern Mariana Islands; and for the "complex volcanic islands of Truk, Yap, Ponape, Palau and the Southern Mariana Islands. A significant elevation of the correlation coefficient occurs only in the test of association of X_3 and population variables for "complex volcanic islands."

Murdock (1963) questions whether the predictable increase in biotic composition and variation with increased vertical range actually appears in Micronesia, and notes the considerable sharing of floral species on Micronesian

TABLE 3. DATA AND CALCULATIONS FOR MICRONESIAN ISLANDS AND ATOLLS, IN 6 GROUPS OF 17 EACH—DEMONSTRATING CONFORMANCE TO MODEL I-A (STANDARD DEVIATION DIRECTLY PROPORTIONAL TO X)

Group No.	ΣX_1	Median, X_1	ΣY_1	S_{Y_1}	Range, Y_1	ΣY_2	S_{Y_2}	Range, Y_2
1	2.303	0.164	1,167	120.4	0 to 406	965	128.3	0 to 503
2	6.504	0.381	3,180	186.8	0 to 570	3,286	200.3	0 to 682
3	11.617	0.719	2,325	182.85	0 to 694	2,553	182.96	0 to 685
4	22.869	1.4165	5,313	323.81	0 to 1,057	5,402	349.95	0 to 1,262
5	45.281	2.785	9,013	569.40	0 to 1,898	9,567	624.24	0 to 1,809
6	95.862	5.500	19,833	783.19	20 to 2,620	19,817	859.85	153 to 3,529
7	870.327	35.046	56,834	4,339.80	37 to 16,402	65,699	5,969.10	0 to 24,139
Totals:	1,054.763		97,665			107,289		

Explanation of symbols used:
X_1 = land area in square statute miles: X_2 = lagoon area in square statute miles;
Y_1 = population, ca. 1935; Y_2 = population, ca. 1948.

coral and volcanic islands. This condition may be a consequence of inadequate information;[4] of the relative geographical isolation of the entire region; of similarities in environmental conditions on coral atolls and islands and on lower portions of volcanic islands; and/or of man's restrictive practices in land use and crop selection.

3. Precipitation. Inadequate meteorological information dictated that testing employ crudely distinguished "non-drought" and "drought" groupings of Micronesian coral atolls and islands. The latter category, its members subject to repeated, prolonged "drought" conditions, includes 14 southern atolls and islands in the Gilbert Islands and Kapingamarangi Atoll in the Caroline Islands.[5] The remarkably high correlation coefficient for association between land area and population for this group prompts the inclusion of this factor in subsequent analysis.

4. Lagoon resources. Despite reports of extensive human exploitation and dependence on lagoon resources, tests of association between population and lagoon area variables produce disappointing, but surprising, results. A moderately high correlation coefficient appears only when considering coral atolls subject to drought. These results might, in part, be ascribed to ignorance of such physical factors as lagoon depth or number and extent of reef passages; these, in turn, would influence the biotic complement of the lagoon. Possibly, also, marked

differences exist between island populations in degree of exploitation of lagoon resources and in dependence upon the products of open sea fishing.

I conclude from the results of these tests that the size of human populations is indirectly and complexly influenced by certain physical and biotic factors of the environment, expressed in the variable "land area." Accordingly, further statistical tests attempt to resolve related issues and extend these initial findings.

TABLE 4. RESULTS OF TESTS OF MULTIPLE CORRELATION, LAND AREA AND POPULATION DENSITY

Category	Number	Sum of Squares			F		
		R_3^2	R_2^2	r^2	Cubic	Quadratic	Linear
All Micronesian Islands and Atolls, $X_1:PD_{Y_1}$	112	0.06206	0.05259	0.02558	1.09	3.11	2.89
All Coral Atolls and Islands, $X_1:PD_{Y_1}$	92	0.04378	0.03924	0.02819	0.42	1.12	2.61
Coral Atolls and Islands, Drought, $X_1:PD_{Y_1}$	15	0.72438	0.58663	0.27304	5.50*	9.10**	4.90*
Coral Atolls and Islands, Non-drought, $X_1:PD_{Y_1}$	77	0.03906	0.03572	0.03043	0.25	0.41	2.36
All Volcanic Islands, $X_1:PD_{Y_1}$	20	0.28801	0.18459	0.06606	2.32	2.47	1.29
All Micronesian Islands and Atolls, $X_1:PD_{Y_2}$	112	0.05002	0.04412	0.02096	0.67	2.64	2.36
All Coral Atolls and Islands, $X_1:PD_{Y_2}$	92	0.02921	0.02735	0.020675	0.17	0.60	1.90
Coral Atolls and Islands, Drought, $X_1:PD_{Y_2}$	15	0.7179	0.5341	0.2508	7.17*	7.30*	4.35
Coral Atolls and Islands, Non-drought, $X_1:PD_{Y_2}$	77	0.02486	0.02475	0.02386	0.008	0.0675	1.83
Volcanic Islands, All, $X_1:PD_{Y_2}$	20	0.35215	0.20727	0.11804	3.58	1.91	2.40

Note: Log (Y+1) employed in these tests.
Explanation of symbols:
X_1 = land area in square statute miles; X_2 = lagoon area in square statute miles;
Y_1 = opuplation, ca. 1935; Y_2 = population, ca. 1948; PD = population density.
* significant at 5% level.
** significant at 1% level.

5. Population density. Population density, an expression of the abundance of organisms, was calculated for all Micronesian islands and atolls. A scattergram of the variables of population density (PD_Y) and land area (X_1) suggested that some form of curvilinear relationship exists. Accordingly, tests of correlation—cubic, quadratic and linear—were performed (Table 4). It is encouraging to note the significant value of F for coral atolls and islands subject to drought. However, I retain some reservation as to the merit of examining an association between two variables, one of which intimately involves the other: Population density = Population/Land area.

6. Multiple Correlation. The possibility that a multiple correlation might

be involved was considered and tests made to determine the relative contribution of land area, lagoon area and population size at an earlier time (Y_1). These tests (Table 5) show a high correlation coefficient of association between population size at Time I and Time II.

7. Bio-physiological environment. No data now available are amenable to objective, quantitative testing of associations of the population size variable

TABLE 5. RESULTS OF TESTS OF MULTILINEAR CORRELATION, MICRONESIAN CORAL ATOLLS AND ISLANDS

Item	Degrees of Freedom	Sum of Squares, in Standard Units	Mean Square	F
Coral Atolls and Islands, N=92				
$R^2_{y.1,2,3}$	(3)	0.88244751		
$r^2_{y.3}$	1	0.87182350		
Effect of X_1 and X_2 after Y_1	2	0.01062401	0.00531200(MS_1)	3.98*
$1-R^2_{y.1,2,3}$	88	0.11755249	0.00133582(MS_2)	
$R^2_{y.2,3}$	(2)	0.87981854		
$r^2_{y.3}$	1	0.87182350		
Effect of X_2 after Y_1	1	0.00799504	0.00799504(MS_1)	5.92*
$1-R^2_{y.2,3}$	89	0.12018146	0.00135035(MS_2)	

Where: $y=Y_2$, $1=X_1$, $2=X_2$, $3=Y_1$.
Formula: $F=MS_1/MS_2$.
* significant at 5% level.

and factors of this environmental level. Although considerable variability in morphological and serological characteristics distinguishes human populations in Micronesia, no consistent patterns of variation accompany the environmental gradients and divisions identified above.

With one possible exception (Maude, in discussion of Rappaport 1963: 147), a diligent review of the literature fails to locate evidence of any differentiating individual bio-physiological adaptations distinguishing among Micronesian populations. Bio-physiological adaptions of individuals to population or community conditions merit additional consideration (see Section 8 below, ff.). Recent studies (Calhoun 1962) suggest that pathological changes may be induced in response to population density factors; the establishment and maintenance of pathogenic and parasitic organisms depend, in part, on the density of human populations in Micronesia (Milhurn 1959), as elsewhere; further investigation will undoubtedly identify associations of such "density-dependent" factors and population density characteristics for grouping of Micronesian islands and atolls.

8. Sociocultural factors. No incisive cultural distinctions accompany those based on physical variability which were identified by statistical analysis,

as discussed in preceding paragraphs. However, this conclusion is admittedly based on sparse ethnographic data.

Geographical proximity for the "Island Group" might be predicted to stimulate common forms of cultural adaptations to similar physical environments and encourage increased contact and interaction between representatives

TABLE 6. LAND AREA, LAGOON AREA, POPULATION NUMBER, AND POPULATION DENSITY OF MICRONESIAN ISLANDS AND ATOLLS, BY ISLAND GROUP

Item	Island Groups						Totals
	Marianas	Carolines	Marshalls	Gilberts	Ocean	Nauru	
Number of islands and atolls	15	46	33	16	1	1	112
ΣX_1	400.020	459.883	70.220	114.120	2.300	8.220	1,054.763
Mean of X_1	26.670	9.997	2.130	7.130	2.300	8.220	56.447
Range of X_1	0.350	0.024	0.060	2.000			
to:					—	—	—
	215.500	188.269	8.510	19.000			
ΣX_2	—	2,020.91	4,353.34	777.60	—	—	7,151.85
Mean of X_2	—	43.93	13.19	48.60	—	—	105.72
ΣY_1	20,747	36,396	10,731	26,242	1,898	1,651	97,665
Mean of Y_1	1,383.13	791.22	325.18	1,640.13	1,898	1,651	7,688.66
ΣY_2	30,308	35,251	10,667	27,709	1,809	1,545	107,289
Mean of Y_2	2,020.53	766.33	323.24	1,731.81	1,809	1,545	8,195.91
ΣPD_{Y_1}	189	18,989	4,545	4,106	825	201	28,855
Mean of PD_{Y_1}	12.60	412.80	137.73	256.63	825	201	1,845.76
ΣPD_{Y_2}	285	17,561	5,201	4,297	878	188	28,319
Mean of PD_{Y_2}	19.00	381.76	157.61	268.56	787	188	1,801.93

Sumary of Island Numbers:
- Volcanic Islands = 20
- Coralline Atolls & Islands = 92
  - Atolls—69
  - "Islands"—23

112

Mean, of Totals: $\overline{X}_1=9.418$, $\overline{X}_2=1.532$, $\overline{Y}_1=872.01$, $\overline{Y}_2=957.94$, $\overline{PD}_{Y_1}=257.63$, $\overline{PD}_{Y_2}=252.85$

Explanation of symbols used:
X_1 = land area in square statute miles; X_2 = lagoon area in square statute miles;
Y_1 = population, ca. 1935; Y_2 = population, ca. 1948 PD = population density.

of the populations of constituent islands and atolls. Areal and population characteristics, by island group, are presented in Table 6. Each island group is characterized by unique associations of land area and population. These may not be ascribed entirely to cultural factors, for common physical and biotic factors also prevail on the islands and atolls of each island group.

A crude test of the effect of cultural factors on population-land area characteristics of island groups assumes that members of island groups sharing relatively more cultural traits will exhibit greater similarity in population-land area characteristics where environmental variables are held constant. A review of historical materials and ethnological interpretation (Matsumara 1918; Mason 1947; Bowers 1950; Joseph and Murray 1951; Gallahue 1947; Fritz 1904; Grimble 1921, *et seqq.;* Doran 1961; Catala 1957; *et al*) indicates that similarities in population-land area relationships might be expected to follow the order: 1) Caroline and Marshall Islands; 2) Caroline and Mariana Islands; and 3) Marshall and Gilbert Islands. A comparison of the population density means (PD_Y) by island group refutes this prediction.

DISCUSSION

Certain suggestive relationships between environment and population have been identified through statistical analysis, but no comprehensive explanation of the sometimes contradictory findings has been advanced. The simplified approach, practicable in initiating this inquiry, must now be succeeded by the development of an economical, logically consistent interpretation comprehending the complexity and interaction of operative factors on organism and population.

Statistical tests (see Table 5) indicate that the major determinant of population size at a given time is the size of the population at an earlier time. Environmental factors can prescribe general limits to population size by affecting individual physiology, thus influencing the birth, death, and survival rates of the populations of particular groups of Micronesian islands and atolls.[6] Practicably, this study considers only three relationships involving environmental factors capable of affecting population size at the level of individual physiology—disease (inter-species), subsistence (community) and social (intra-species) relationships.

1. Disease. Disease has been indicted by many students as the major determinant of the "environmental resistance," or difference between actual and potential population increase, of Micronesian peoples (Lessa 1955; Thompson 1945; Yanaihara 1940). Despite incomplete, fragmentary, and even contradictory reports, a vast body of evidence implicates disease as exerting a major influence on population characteristics.

The populations of the volcanic islands may have suffered disproportionately from decimating epidemics of "rheum," "putrid fever," measles, influenza, smallpox, whooping cough, and other often unspecified diseases, but these diseases and others, including syphilis,[7] gonorrhea, and tuberculosis, were also spread to coral atolls and islands by direct foreign contact and by native emigres from volcanic islands (Fritz 1904; Hermann 1910; Yanaihara 1940; McNair, *et al.*, 1949). Lacking bodily immunity or natural predators of invading pathogens, Micronesians of all ages and both sexes died during these epidemics, thus reducing population size at various time periods and the breeding population of the next and succeeding generations. General debility in survivors may have had some effect on longevity and fecundity, and at least one of these diseases, gonorrhea, has been confirmed as a cause of infertility and sterility (Boyd 1949).

Such features of the physical and biotic environmental levels as harbor conditions, geographic position, and availability of water and food resources, no doubt, influenced the selection of various islands as centers of foreign occupation and, thus, disease exposure. Differences in the onset, rate, and course of disease incidence and population decline in various volcanic islands closely parallel differences in time, form, and intensity of alien intrusion. *The long-range effect, however, has been that areas of greater exposure have been the recipients of ear-*

lier and more extensive attempts to alleviate these very effects, through the provision by foreign agencies of hospitals, medical care, and educational facilities. Access to these, and the development of surviving populations with acquired immunity levels, are reflected in population size increases, commencing about 1786 in the Marianas Islands, site of early Spanish occupation and development of a Pacific fleet way-station. In the Kusaie and Ponape Islands, both major whaling ports of the 19th century, the declining population growth curve was reversed in the early part of the 20th century, but in the Palau and, particularly, Yap Islands, this reversal was further delayed.

In some of the coralline islands and atolls, at least, foreign settlement has also been followed by epidemics and population decline, as in the Marshall Islands, but one is continually impressed, in reviewing the literature, by the probably greater effect which typhoons, or tropical cyclones, have exerted on the population characteristics of coralline islands and atolls (Hermann 1910; Tolerton and Rauch 1950; Weckler 1949). Despite efforts by foreign agencies, the loss of human life and devastation of biota caused by typhoons have been great. Although disease and parasitism are not unknown on the coral atolls and islands (Miller 1953; Lessa and Myers 1962; Conard *et al.,* 1960), it is on the volcanic islands that disease probably operated most effectively on the birth, death, and survivorship rates of earlier Micronesian populations.

The more numerous populations of volcanic islands probably provided better conditions for the establishment of parasitic and pathogenic animal populations (Milhurn 1959). Further, the greater disruption of native customs and practices occasioned by extensive alien influence in the volcanic islands may have accelerated the progress of disease and population decline. Enforced settlement of natives in limited living areas, as in the Mariana Islands, discouragement of native sanitation techniques, and the transfer of laborers to other islands or lands, are all examples of modifications of customary practices capable of affecting population characteristics.

Features of the physical, biotic, and sociocultural environment which, primarily through disease, affect human physiology influenced the birth, death, and survivorship rates of Micronesian populations. These features and effects, and the consequent influence on population characteristics, differ between volcanic and coralline islands, providing some basis for the interpretation of certain of the results of earlier statistical analysis.

2. Subsistence. Availability of food constitutes a potential determinant of population size and growth. Although the inventory of food resources in a given setting is dependent on the physical and biotic components of the environment, human exploitation of these resources is determined, in large measure, by sociocultural factors.

Fishing and horticultural pursuits dominate the exploitative activities of Micronesian populations and, as already stated, certain plants are cultivated and/or consumed throughout Micronesia. Differences do exist in the relative contribution of various plant and animal foods in the dietary, in the extent to which available land area is devoted to exploitative endeavors, in the manner of distribution of food and of the essentials of production, and in other respects. Reversion to the previously identified dichotomy in population characteristics may help to explain some of these differences, as well as the population size and density differentials of volcanic islands, as contrasted with coralline islands and atolls.

Estimates of the amount of potentially arable lands in the Trust Territory suggest that a greater percentage of total area of coralline lands *can* be used for the cultivation of crops than is generally true for the volcanic islands (United States Department of the Navy, *Annual Reports* 1, et seq.), and some studies have confirmed that a greater percentage of the total land area of certain coralline islands and atolls *is* used for horticultural purposes (Macmillan 1946; Useem 1946; Hatheway 1953). On occasion, expansion of cultivated areas may even threaten the survival of an atoll population, as occurred on Mokil Atoll (Weckler 1949). And while exploitation of lagoon and reef resources is reported for all islands and atolls, differences do occur among island populations as to the intensity of sea fishing. The inhabitants of such coralline islands and atolls as the Marshall Islands, Gilbert Islands, and various Caroline Islands, such as Woleai and Nukuoro, have been singled out by numerous observors as the sailors and sea-fishermen of Micronesia.

In the Gilbert Islands, where drought conditions affect 14 of 16 islands, fishing techniques are diverse, accompanied by an extensive lore and formalized patterns of catching and distribution. Moreover, the Gilbertese uniquely, or to marked degree, practice crop fertilization, construct aroid (*babai*) pits and reportedly consume a wider range of available plant foods than do other Micronesians (Catala 1957; Luomala 1953).

Several of the authorities quoted above have commented on the amount of unexploited land area, usually at higher elevations, on various volcanic islands. MacMillan contends that crop areas could be extended to higher elevations on volcanic Caroline Islands, and the ability of the Yapese and Kusaieans to survive deprivations of the war years without evidence of marked malnutrition, even when living at higher altitudes than usual, suggests that disuse of land is not entirely dictated by any physical, biotic or biophysiological limitations (Duncan 1946; Lewis 1949). On the Truk Islands, in contrast, displacement of the native population during the war years only partly involved movement to higher elevations, and medical diagnosis indicated that the natives suffered extensively from disease and malnutrition during that period (Hall and Pelzer 1946).

In addition, various reports indicate that the native peoples of at least some volcanic islands have tended to emphasize one or a few food crops at the expense of others. Pandanus and yams, for example, have been relegated to the position of "last choice" foods on the Truk Islands, while breadfruit becomes the *sine qua non* of a meal. In the Palau Islands, taro and yams are the *pièce de résistance* of an acceptable meal, but on the Ponape Islands, yam and breadfruit constitute the vegetable mainstays. Yet, evidence of physical and biotic limitations on the successful cultivation of these and other food plants is more convincing for the coral atolls and islands. To some extent, cultural selection prevails throughout Micronesia, but it appears that the luxury of arbitrary rejection of available food resources is particularly noticeable on the lush, watered volcanic islands.

In recent decades, at least, exploitation of the resources of the volcanic islands has been adequate for the maintenance of the native population, although this need not have been the case in the pre-Contact and early Contact periods. Famines have been recorded, however, for several coralline islands and atolls, notably for those subject to drought or to typhoon destruction.

Less immediate nutritional effects on population characteristics are difficult to evaluate, particularly since "minimal standards" are rarely available for non-Western peoples and foods, except by extrapolation from studies of Western foods and peoples. Nutritional studies in Micronesia (Alpert 1946; Murai 1954; Turbott 1954, 1949) have failed to identify more than occasional cases of marked malnutrition, although Greulich (1951) and Joseph and Murray (1951), among others, have spoken of nutritional inadequacies in Micronesian populations. No nutritional studies in Micronesia have reported on the presence or absence of Vitamin E, the only vitamin suggested to have some direct relationship to fertility, in the Micronesian dietary.

A relative shortage of food, far more often than any absolute scarcity, is capable of affecting the mortality rate of Micronesian populations. Such shortage depends on physical and biotic factors, but, to an important extent, on cultural components of the environment, also. Differential operation, weight and interaction of all three factors are reflected in some of the distinguishing characteristics of the populations of volcanic islands and of coralline islands and atolls. No convincing evidence indicates that either the birth or survivorship rates of Micronesian populations are directly influenced by either relative or absolute food scarcities.

3. Intra-species relationships capable of affecting population characteristics are so numerous and diverse that only a limited number may be considered here. The provision of the requisite host conditions for the establishment of populations of pathogens and predators has been considered above in discussing disease conditions. Competition for the necessities of life, never limited in human societies to the provision of materials required for mere biological survival and reproduction, covers a wide range of human behavior capable of affecting individual physiology and influencing population characteristics.

Although interpersonal conflict has been repressed by alien administrators and missionaries, a few reports indicate that unrestricted "warfare" caused relatively few direct deaths, although destruction of crops and the abduction of conquered women may have had more extensive, long-term effects on population characteristics (Girschner 1913; Emory 1948). Armed conflict with foreign forces in the Mariana Islands and on Ponape resulted in the death of many natives and in population transfers (Joseph and Murray 1951; Bascom 1950a, 1950b). Changes in population characteristics due to warfare and also from loss of life at sea have undoubtedly been effectively reduced by foreign administrative policies.

If Micronesian peoples practiced abortion or infanticide in the past (Fritz 1904; Kotzebue 1821), Christianization has probably mitigated against such practices in recent years, although some students report the use of abortifacients and contraceptives today (Thompson 1947; Schneider 1955).

Social, as well as biological, structuring characterizes Micronesian populations, past and present, and, as indicated by the studies of Petrusewicz (1957), population structure may be an effective variable of certain mammalian population characteristics. An hierarchical class system, accompanied by behavioral, sumptuary and marital proscriptions and prescriptions, may reduce the availability of suitable mates, may result in increased age-at-marriage for spouses, encourage sexual abstinence in conformance with these or associated dicta, and in these, as also in other ways, influence birth rates of populations through restriction of breeding behavior.

A general association between social stratification, population size, and "ecological efficiency" of Micronesian populations has been identified. Social stratification, as described, has been most fully expressed on certain volcanic islands in Micronesia, although some degree of social stratification also characterizes many Micronesian coral atolls and islands. Of these volcanic islands, social stratification is more complex and more effectively maintained on the Yap Islands, whose rolling hills may be almost entirely cultivable and whose population density is quite low. At the other extreme stands the Truk Islands, where class structuring is minimal, breadfruit crops are grown over much of the land, and population density is maximal for volcanic islands. Other Micronesian volcanic islands, particularly in the Caroline Islands, occupy an intermediate position in respect to these three features. However, even if earlier population data reports were accurate, it would be difficult to extrapolate this relationship to interpretation of conditions in remote time periods, since variation in any one feature should result in accommodations of the remaining factors.

SUMMARY AND CONCLUSIONS

An attempt has been made here to identify the nature of the relationship between environment and human population size in Micronesia. Statistical tests, establishing the association of population size and the complex of environmental features subsumed in the categories of "land size" and "lagoon size" indicate that population size at one time period is a product of the size of the population at a preceding time period. Some of the variables and processes involved in the establishment and maintenance of such associations as those identified between population size and geological composition, meteorological conditions and biotic characteristics of Micronesian islands and atolls have been examined.

Although other factors[8] may yet be found to contribute importantly to these associations of environmental features and human population characteristics, the results of this study indicate the following:

1. The observed relationships of population characteristics and environmental factors are explicable in terms of the operation of four environmental components—physical, biotic, bio-physiological, and socio-cultural—and the interactions between and among these components, particularly as these impinge upon the bio-physiology of the individual and, in turn, are expressed in such population characteristics as birth, death, and survivorship rates.

2. The operation of a larger number of effective factors and/or interaction of factors results in the reduction of range and variation in population characteristics exhibited, thus accounting for the restriction of range and variation of population density figures at two time periods for Micronesian volcanic islands, in comparison to those for neighboring coralline islands and atolls. As a result, predictions of variations in population number are more accurate for volcanic than coralline land forms (cf. Hamilton, *et al,* 1963).

3. In contrast to the results of some other studies (Birdsell 1957), mere availability of food does not now appear to be a major population depressant in Micronesia. However, the Micronesian data, as interpreted, indicate that certain cultural variables which may act as population size depressants are differentially operative, depending on the limitations of the physical and biotic environment. This results in an association of beneficent physical and biotic environment, socio-cultural complexity and reduced population density, or, conversely, of restricted physical and biotic potential, reduced sociocultural elaboration, and increased population density.

4. By the criterion of relative abundance, certain human population characteristics of Micronesian islands and atolls are inversely related to the elaboration of particular sociocultural phenomena, namely, those associated with social stratification. Thus, the population density figures characterizing the volcanic islands, as a group, are below those for the coralline islands and atolls, as a group, while social structuring of the population is more extensively developed on the former group of islands.

Other studies, notably by Birdsell (1953), have identified an association between population size, physical and biotic environmental factors, and certain sociocultural phenomena among hunting and gathering, tribally-organized peoples. Several limited attempts to interpret the relationship between selected environmental features and population characteristics of Pacific island peoples have also appeared recently (Alkire 1960; Mason 1959; Sahlins 1958). Application of an ecological viewpoint to problems involving such island populations may be expected to produce some important advances in our understanding of human evolution. In the words of one eminent ecologist: "All of the laws that control number, kind and interaction between organisms must therefore have their full operation within the limits of such an (island) area" (Slobodkin 1963:21).

These findings suggest that careful consideration must be given to the proposition that culture is biological adaptation. The criterion of relative abundance, despite its currency and practical advantages, may be a poor measure of evaluation; the proposition may be valid only in some very broad sense; or it may be necessary to identify specific cultural features as eufunctional, afunctional or dysfunctional in biological adaptation. This inquiry indicates that, pending further studies, this view cannot be endorsed without qualification.

NOTES

[1] This paper is based in part on the author's Ph.D. dissertation (University of California, Los Angeles). I would like to take this opportunity to express my deep appreciation to Dr. Joseph Birdsell for inspiration, advice, encouragement, support and tolerance over many years.

[2] These concepts and others to follow are derived from, or suggested by, the writings of many ecologists, among which I would particularly recognize the following: Odum and Odum (1959); Allee, *et al* (1949); Bates (1953); Elton (1927); and Andrewartha (1961).

[3] The linear regression (model I) and rank correlation tests applied to this data were performed with the aid of a Monroe calculator. With the assistance of a research grant from the Committee on Research, University of California, Riverside, all other statistical tests were carried out at the Computing Center, University of California, Riverside, where an IBM 1620 computer was made available for this purpose. I wish to acknowledge the invaluable advice and assistance so generously provided by Dr. Morris Garber of the Computing Center, and the patient instruction and performance of computer operations provided by Miss Marsha Dougall. Dr. Garber has contributed whatever of merit exists in these statistical analyses; faults are entirely the responsibility of the author.

[4] Merrill (1946) has reported some 1300 floral species for Micronesia and estimates that only seven endemic genera are represented in the 620 genera present. Geographical isolation and relatively limited time period for the development of endemic forms are probable determinative factors of these conditions. Unfortunately, the very complexity of the volcanic islands has precluded the preparation of detailed ecological studies comparable to those available for some of the coralline islands and atolls.

[5] Seasonal dry periods are recorded in much of Micronesia, particularly in the northern Marshall Islands (Fosberg 1955) and rainfall gradients have been noted for islands of one environmental category of a single island group (Manchester 1951). In no case, however, do these periods of limited rainfall permit the designation of "drought" conditions comparable to those found for the islands and atolls discussed above.

[6] Odum and Odum (1959) specify as characteristics of the population: growth form, dispersion, biotic potential, age distribution, mortality, natality and density.

[7] Yaws may have been present in Micronesia before Contact (Steward and Spoehr 1952), but on Kusaie, at least, either an erroneously labeled "yaws" (syphilis?) or perhaps some new, virulent form of *Treponema pertenue,* attacked the native population in the post-Contact period (Lewis 1949).

[8] Population size variability for some Micronesian islands and atolls is party explicable in terms of a variety of known reasons. For example, changes in population size for Eniwetok, Bikini, Kwajalein, Rongerik and Kili are largely a direct consequence of removal and settlement as a result of Atomic Energy Commission activities in Micronesia. The burgeoning post-World War II growth of the population of administrative centers in the Marianas Islands, Majuro, Tarawa and elsewhere is partly a consequence of native movement to areas of economic opportunity. Nonetheless, only a minute part of population size variability over a very limited time period is thus accounted for.

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