POPULATION GROWTH, DENSITY AND TECHNOLOGY IN THE WESTERN EUROPEAN MESOLITHIC: LESSONS FROM ANALOGOUS HISTORICAL CONTEXTS

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ABSTRACT: In this paper the relationship between population growth and technological development, as postulated by Oswalt (1976) and by Boserup (1981), is investigated. Its strength and causation is tested by using an objective measure of technological development, which is relevant for foraging and simple farming societies. It is proven that the functional taxonomy of subsistence equipment, as used by Oswalt, cannot be isolated from its concomitant social context. An increase in functional/social complexity is correlated with population density. Technological complexity, population density and milieu form an indivisable triangle of inter-relationships which have the potential for joint evolutionary development. These conclusions can be applied to the Western European Mesolithic.

KEYWORDS: Western European Mesolithic, technology, population density, social complexity, social evolution, foragers, simple farmers, ethnographic analogy, North American Indians.

1. INTRODUCTION AND PROBLEM STATEMENT

Recently the interrelationship between population growth and density and technological development has been considered in the light of evolutionist theory (Oswalt, 1976) and broad propositions of the development of civilization (Boserup, 1981). In her latest work *Population and Technology*, Boserup (1981) surveys the development of technology and claims to relate same to population growth and density. She suggests that a relationship between these three factors is extant on a world-wide scale and throughout the history of mankind. She takes the position that the increases in both food production and sedentism are correlates of a growing technological complexity and development, which must inevitably lead to growing population numbers and densities. In this paper that interrelationship is first examined on a general level and then related to the Western European Mesolithic specifically.

The validity of a general relationship between population growth and technological development cannot be denied. However, by merely taking that position Boserup tells us little about its strength or its causation. Her first and basic need is that of an objective measure of technological development, which is cross-culturally valid and which can be related to other relevant cultural variables. We doubt that it is possible to design a measure which is valid for all the different cultures which Boserup uses. Because our prime concern is the Western European Mesolithic, we have sought measures which would be suitable to both the Mesolithic and analogous aboriginal situations.

One measure to study technological development in simple societies was designed and used by Oswalt (1976) in his examination of subsistence technology. That examination was made to test his explicitly evolutionary hypothesis that material culture, and especially subsistence equipment, has evolved from a few, generalized, simple forms to many, specialized, complex forms (Oswalt, 1976: p. 35), because technological change is cumulative (Oswalt, 1976: p. 199). However, we will demonstrate that:

1. The attributes chosen by Oswalt to measure technological development are not optimal and in fact support the antithesis of his hypothesis,
2. The inter-relation between the variables which he studies is more complex than he acknowledges,
3. Technological complexity is not synonymous with technological development, and that
4. The statistical analysis of Oswalt's original data and an additional factor, population density, indicates that an assessment of technological complexity or development cannot be made in a sociocultural vacuum.

Through an analysis of his data and our demographic data, it will become clear that:

a. The functional taxonomy of subsistence equipment cannot be isolated from its concomitant social context,

b. Technological development is best expressed as the increase in functional/social complexity,

c. That relationship is best rendered when the percentage of facilities is correlated with population density per society, and that

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d. The interaction between functional complexity and social complexity occurs at a higher level than that between each and the natural milieu. Our analysis indicates that technological complexity, population density, and milieu form an indivisable triangle of inter-relationships which have the potential for joint evolutionary development. Such development is not inevitable and, *contra* Boserup, is not extant on a world-wide scale. Nor is the rate and direction of that development constant and linear. Instead, it is highly variable and dependent upon the socio-cultural context of each society.

A similar variability characterizes the Mesolithic societies of Western Europe. Some display a temporal increase in functional complexity of subsistence equipment. They all show an increase in population density and a clinal trend toward increased social complexity and sedentism. These factors indicate a trend away from extensive land-use toward intensive land-use, increased territoriality and border maintenance, approaching or achieving levels currently recorded or suggested for the Neolithic (Carneiro & Hilse, 1966).

2. TECHNOLOGICAL COMPLEXITY AND ITS CORRELATES

In his analysis of technological development, Oswalt considered the subsistence technology to be the most diagnostic. He employed two primary variables: 1) the number of subsistants, and 2) the number of technounits composing each subsistant. He defined a subsistant as 'an extrasomatic form that is removed from a natural context or manufactured and is applied directly to obtain food' (Oswalt, 1976: p. 46), *e.g.* an arrow. A technounit he defined as 'an integrated, physically distinct, and unique structural configuration that contributes to the form of a finished artifact' (Oswalt, 1976: p. 38). If that arrow consists of a flint point and a wooden shaft, it would have two technounits. Furthermore he recognized a third dimension to subsistence technology, *i.e.* the manner in which and the prey upon which the diverse subsistants were used. To these taxa definitions we would like to add that of social context, *i.e.* the ownership and the private or corporate basis of the use or exploitation of the equipment. The reasoning behind this definitional addendum will become apparent below.

Instead of a linear continuum of complexity, Oswalt suggested four distinct modes:

1. Portable and potentially expedient *instruments*, which were made by, used by, and belonged to individuals;

2. Portable and potentially expedient *weapons*, each designed to maim or kill their prey and which were made by, used by, and belonged to individuals;

3. Semi-permanent and permanent fixed facilities which were actively tended and exploited by their builders. Generally such *tended facilities* were not individually owned, but rather were owned and utilized by a larger corporate/social unit, *e.g.* extended family, lineage, band, clan, *etc.*;

4. Semi-permanent and permanent fixed facilities which were so designed as to perform their task without constant human intervention or help. Again these *untended facilities* were not individually owned, but rather were owned, maintained and operated by a larger corporate unit than the individual.

Having formulated this inductive taxonomy, Oswalt drew a sample of 36 societies from five major geographic regions, *i.e.* arctic, sub-arctic, temperate, desert and tropics, and two primary subsistence modes, *i.e.* foraging, and simple cereal and/or root crop farming. This sample he used to examine his hypothesis of technological development. All variables, *i.e.* the numbers of subsistants and the numbers of technounits per subsistant, are measurable (countable) for each of the functional taxa and for each society. Their measurement is not depend-

Table 1. Descriptive statistics[1] of the total number of subsistants, total number of technounits, and mean number of technounits per subsistant for the total sample of 36 societies.

	Min.	Max.	Mean	Median	S.d.	St. error	Var. coeff.	Skewness	Kurtosis
Total number of subsistants	11	65	32.639	34.750	14.385	2.397	.441	.057	.825
Total number of technounits	14	296	122.750	119.500	72.691	12.115	.592	.395	.807
Mean number of technounits per subsistant	1.273	6.121	3.561	3.346	1.175	.196	.330	.371	.754

1. All calculations have been performed in the respective module of the WESP package of interactive statistical programs (v.d.Weele 1977). Kurtosis was determined using the small sample method (Geary, 1936). All skewness and kurtosis values indicate non-significant departures from normality. However, all distributions are extremely variable, as demonstrated by their high variation coefficients.

ent upon the cultural context in which they occur.

As a measure of technological development Oswalt used technological complexity, *i.e.* the average number of technounits per subsistant. The descriptive statistics of his data base are presented in table 1.

Plotting the total number of technounits and the total number of subsistants per society, taken from Oswalt's figures 9-1 and 9-2, yields the following scattergram (fig. 1).

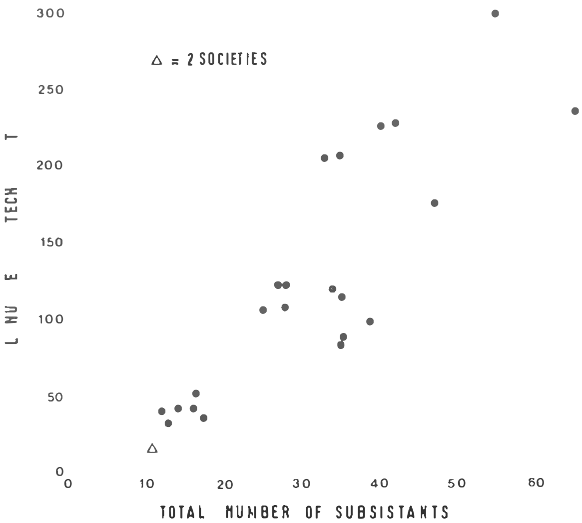


Fig. 1. Scattergram of the total number of subsistants and the total number of technounits per society for the total sample of 36 societies (from Oswalt, 1976: pp. 189-190).

Visual inspection of his plots led Oswalt to suggest a roughly linear relationship. This has been subsequently confirmed by us, *i.e.* the Spearman rank correlation coefficient between the numbers of subsistants and the numbers of technounits is .883 ($p<.001$).[1] The result agrees with Oswalt's statement that 'The increase of subsistants and technounits is lineal for foragers and farmers alike, but the progression is more orderly for farmers' (Oswalt, 1976: p. 190; *vide* fig. 2). Conversely such a linearity is the antithesis of the cumulative growth in complexity upon which his hypothesis depends and which he would rather see as a sigmoid curve (Oswalt, 1976: p. 199). Moreover, in this form the data reveal nothing about the cause of the linear relationship nor about any inherent evolutionary trends. In order to trace such causalities or trends, Oswalt re-cast the data in such a form that technological complexity could be tested for correlation with the following, potentially contributing, variables: economic mode, milieu or environmental dependence, and subsistant taxonomy (function). Following his reasoning, we evaluated the strength of his arguments by means of the relevant statistical procedures. The raw data for these procedures have been taken from Oswalt and are presented in Appendix A.

For nominally partitioned ordinal data, three statistical approaches are available. Firstly they can be plotted and subjected to visual inspection, as was done above for the total material. Secondly

Table 2. Descriptive statistics[1] of the total number of subsistants, total number of technounits and mean number of technounits per subsistant for 36 societies, partitioned by economic mode.

	Min.	Max.	Mean	Median	S.d.	St. error	Var. coeff.	Skewness	Kurtosis
Foragers n = 20									
Total number of subsistants	11	55	28.550	28.000	13.543	3.028	.474	–	.827
Total number of technounits	14	296	122.950	112.500	83.870	18.754	.682	–	.810
Mean number of technounits per subsistant	1.273	6.121	3.901	4.000	1.437	.321	.368	–	.825
Farmers n = 16									
Total number of subsistants	14	65	37.750	37.500	14.154	3.538	.375	–	.760
Total number of technounits	36	230	122.500	126.500	58.474	14.618	.477	–	.806
Mean number of technounits per subsistant	2.118	3.889	3.135	3.056	.506	.126	.161	–	.765

1. For samples under 25, skewness figures are inappropriate because they cannot be evaluated by current methods. For the kurtosis evaluation, vide footnote 1, table 1.

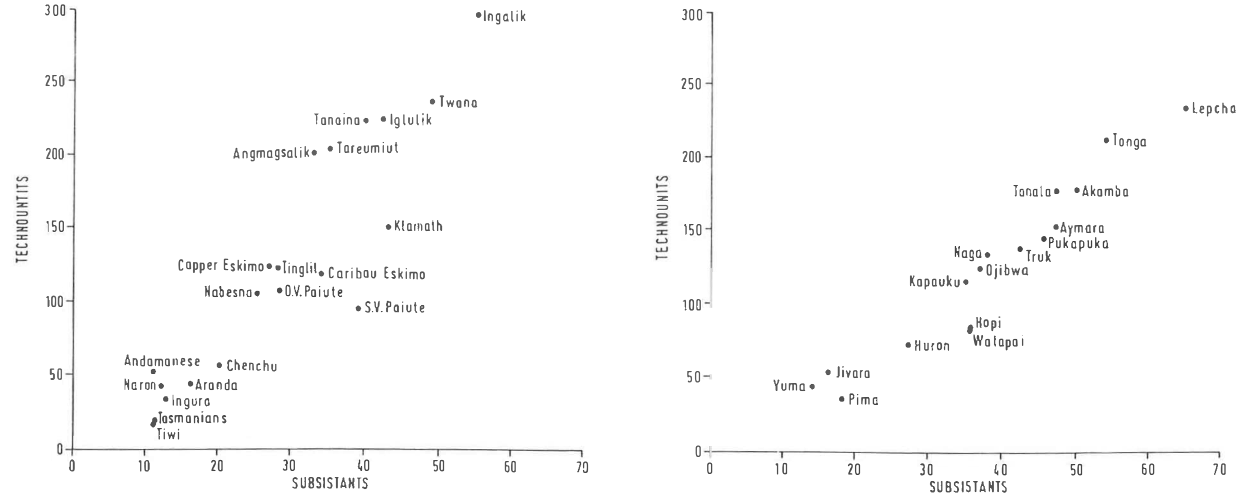


Fig. 2. Scattergrams of the total number of subsistants and the total number of technounits per society, partitioned by economic mode (after Oswalt, 1976: pp. 189-190).

rank correlation coefficients can be determined to evaluate the mutual relationships, and thirdly groups of relevant attributes can be compared by Mann-Whitney U-tests.[2] Unless there are problems of hyperprobability due to small sample size, all three methods are used for each partitioning.

Beginning with the analysis of the economic mode, we have partitioned Oswalt's sample into two groups, *i.e.* foraging *versus* farming societies. The relevant figures are presented in table 2 and rendered as plots in figure 2.

Visual inspection of figure 2 indicates that both plots reflect the linearity found in the plot of the combined data (fig. 1). Their Spearman rank correlation coefficients are both significant (table 3).

Mann-Whitney U-tests of the two distributions reveal no statistically significant differences (table 4).

Obviously the simplistic expectation that the technological complexity of a society should increase with the 'evolution' of the subsistence level from foraging to simple forms of farming is contradicted by the data. Although the farming societies possess the highest maximum numbers of subsistants (*vide* fig. 2, table 2, and Appendix A), the foragers have the highest numbers of technounits and therefore more 'complex' equipment, using Oswalt's criteria. This result indicates either that Oswalt's hypothesis is invalid or that the mean number of technounits per subsistant is an ineffective measure of evolutionary progress. The above result also raises the question of the appropriateness of indiscriminate mixing of the two economic modes in the following geographic partitioning.

In the second instance, Oswalt partitioned his data according to the five major geographic regions of his sample.[3] In order to assess milieu or environmental dependence, he calculated the mean number of technounits per subsistant for each region. The relevant data are given in table 5, below.

The plots of the numbers of subsistants and technounits per society in each of the five partitions are presented in figure 3.

Visual inspection of these plots would seem to

Table 3. Spearman rank correlations between the total number of subsistants and the total number of technounits in 36 societies, partitioned by economic mode (Siegel, 1956).

	r_s	N	p
Foragers	.905	20	$<.0005$
Farmers	.987	16	$<.0005$

Table 4. Mann-Whitney U-Test of the technological attributes in 36 societies, partitioned by economic mode (Siegel, 1956).

	Sample size Foragers	Sample size Farmers	U	p
Total number of subsistants per society	20	16	98.0	= .025
Total number of technounits per society	20	16	149.0	$>.050$
Mean number of technounits per subsistant per society	20	16	98.0	= .025

Table 5. Descriptive statistics[1] of the total number of subsistants, total number of technounits, and mean number of technounits per subsistant in 36 societies, partitioned by geographic region.

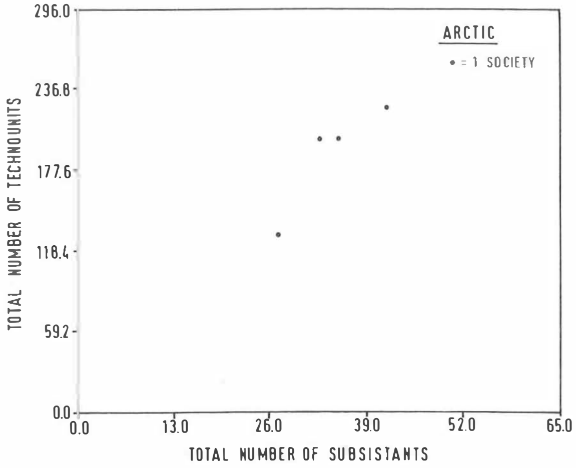
	Min.	Max.	Mean	Median	S.d.	St. error	Var. coeff.	Skewness	Kurtosis
Arctic n = 4									
Total number of subsistants	27	42	34.250	34.000	6.185	3.092	.181	–	–
Total number of technounits	122	225	188.500	203.500	45.494	22.747	.241	–	–
Mean number of technounits per subsistant	4.519	6.121	5.464	5.500	.705	.353	.129	–	–
Subarctic n = 4									
Total number of subsistants	25	55	38.500	37.000	12.610	6.305	.328	–	–
Total number of technounits	105	296	185.750	171.000	90.791	45.395	.489	–	–
Mean number of technounits per subsistant	3.471	5.600	4.663	4.500	1.005	.503	.216	–	–
Temperate n = 8									
Total number of subsistants	11	65	38.250	40.000	16.412	5.803	.429	–	–
Total number of technounits	15	237	137.375	136.000	74.500	26.340	.542	–	–
Mean number of technounits per subsistant	1.364	4.938	3.353	3.500	1.069	.378	.319	–	–
Desert n = 8									
Total number of subsistants	12	39	24.500	22.500	10.941	3.868	.447	–	–
Total number of technounits	36	107	66.500	63.000	29.116	10.294	.438	–	–
Mean number of technounits per subsistant	2.118	3.821	2.778	2.500	.578	.204	.208	–	–
Tropics n = 12									
Total number of subsistants	11	54	31.833	36.500	16.486	4.759	.518	–	.891
Total number of technounits	14	210	107.583	123.000	64.852	18.721	.603	–	.861
Mean number of technounits per subsistant	1.273	4.636	3.219	3.167	.824	.238	.256	–	.637

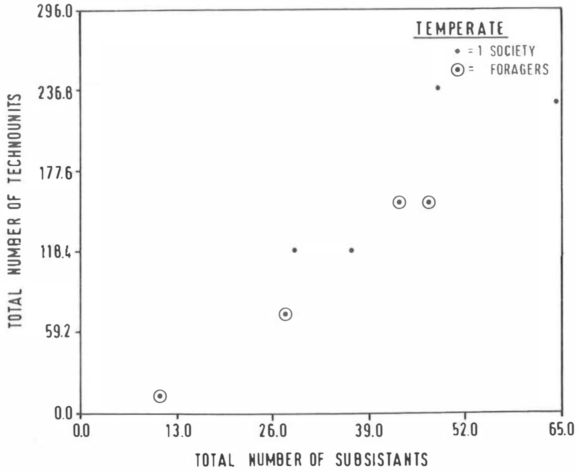
1. Vide footnote 1, table 2. The kurtosis of the mean number of technounits per subsistant in the tropics showed a significant departure from normality in a negative direction.

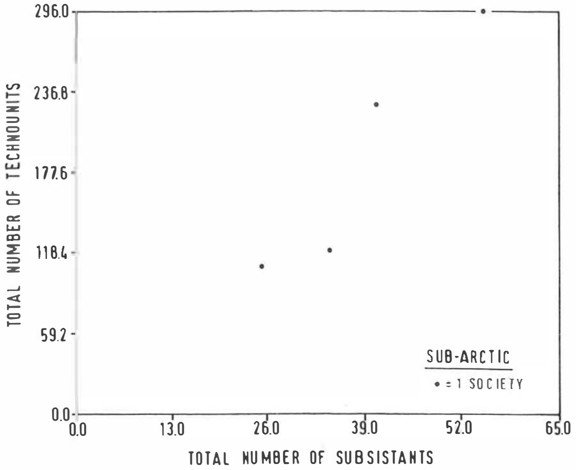
confirm the linearity proposed by Oswalt for all geographic partitions except for the desert, where the relationship appears more curvilinear. These impressions have been confirmed by Spearman rank correlation coefficients, although sample size precludes definitive assessments for the arctic and sub-arctic regions (table 6). Visual inspection would also suggest strong differences between some of the regions, but sample size again precludes valid testing of these impressions.

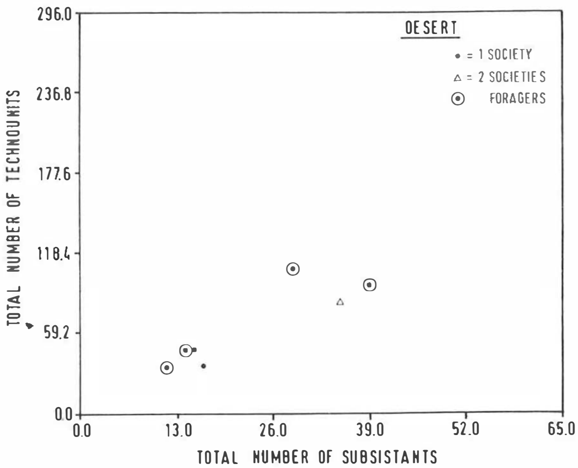
Table 6. Spearman rank correlations between the total number of subsistants and the total number of technounits in 36 societies, partitioned by geographic region (Siegel, 1956).

	r_s	N	p
Arctic	1.000	4	.05
Sub-Arctic	1.000	4	.05
Temperate	.970	8	$\leq .01$
Desert	.683	8	$\leq .05$
Tropics	.981	12	$\leq .01$









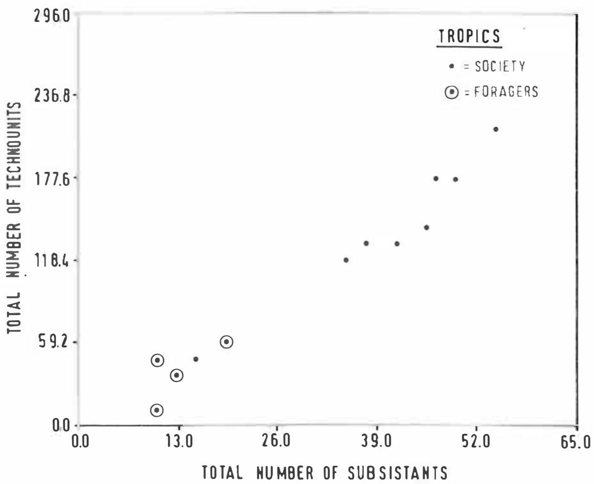


Fig. 3. Scattergrams of the total number of subsistants and the total number of technounits per society, partitioned by geographic region.

What these plots also show is that the two economic modes, foraging and farming, are not spread equally through all three regions in which both occur. Both the numbers of subsistants and the numbers of technounits per society show a tendency toward bimodality in the tropics region. All four of the tropics foraging societies cluster in the lower mode of both variables with but one of the eight tropics farming societies. This inherent sample skewing is not revealed by the correlation coefficients.

Because the geographic partitions may be arranged along an ordinal scale, according to the four ecological attributes of the regions, we could test the relationship between the mean number of technounits per subsistant in each region and the rank score of the regions along that continuum (Oswalt, 1976: table 8). A Spearman rank correlation of 1.000, $p = .02$ was obtained (in this case the test was done for a two-tailed probability, since we did not have a theoretical expectation of the direction of the relation). At face value, this result would indicate that technological complexity is closely related to milieu as defined above. However, before relegating all, or even most variation in technology to the vagaries and vicissitudes of milieu, we must realize that this variation may be more complex than suggested by the above correlation, based on regional means. This latter possibility was proven to be true when we proceeded with our statistical analysis of all the constituent data. Examining the variation in technological complexity between all the societies in each of the five major geographic regions we found an inherent three-fold grouping of the data which is presented in table 7 and figure 4.

The foregoing analysis indicates that there are three overlapping groups of milieu-related technological complexity, *i.e.* 1. arctic and sub-arctic, 2. sub-arctic, temperate and tropics and 3. temperate, tropics and desert.

Instead of the linearity suggested by the rank correlation coefficient run on the regional means, this analysis of the full range of variation indicates that the apparent relationship with milieu is more complex. It also serves to illustrate the dangers inherent in uncritical lumping of the data and in accepting *prima facie* 'environmental dependence'. The factor milieu, although important, seems to explain only part of the technological variation when used at a world-wide scale. It cannot be cited as the

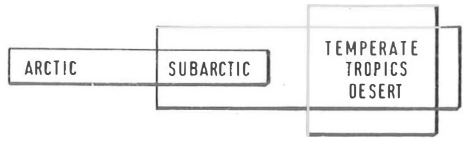


Fig. 4. Statistical affinities of the distributions of the mean number of technounits per subsistant in 36 societies, partitioned by geographic region.

Table 8. Mean number of technounits per society in five geographic regions, partitioned by economic mode (after Oswalt, 1976: p.182).

Region	Economic mode:	Mean number of technounits per subsistant: Foraging	Farming
Arctic		5.5 (N = 4)	–
Sub-Arctic		4.8 (N = 4)	–
Temperate		4.0 (N = 4)	3.3 (N = 4)
Desert		3.0 (N = 4)	2.4 (N = 4)
Tropics		2.8 (N = 4)	3.4 (N = 8)[1]

1. This figure is the mean of all tropical farming societies.

Table 7. Mann-Whitney U-Test of the mean number of technounits per subsistant in 36 societies, partitioned by geographic region[1] (Siegel, 1956).

	Arctic N = 4	Sub-Arctic N = 4	Temperate N = 8	Desert N = 8	Tropics N = 12
Arctic	–				
Sub-Arctic	U = 4.0 p = .342				
Temperate	U = 1.0 p .008	U = 6.0 p = .110			
Desert	U = 0.0 p = .004	U = 1.0 p = .008	U = 17.0 p = .130		
Tropics	U = 1.0 .020 > p > .002	U = 6.0 .050 > p > .020	U = 41.0 p > .100	U = 27.0 p > .100	–

1. The Mann-Whitney U-Test of the total number of subsistants per society yielded no probabilities which were < .10. The analysis of the total number of technounits per society yielded results which largely confirmed those shown in Table 7. They are presented in Appendix B.

Table 9. Descriptive statistics[1] of the total number of subsistants, total number of technounits, and mean number of technounits per subsistant, partitioned by functional taxon.

	Min.	Max.	Mean	Median	S.d.	St. error	Var. coeff.	Skewness	Kurtosis
Instruments n = 36									
Total number of subsistants	1	14	5.833	5.500	3.140	.523	.538	.718	.814
Total number of technounits	1	32	11.306	11.500	6.568	1.095	.581	1.073 $p < .02$	.740 $.05 > p > .01$
Mean number of technounits per subsistant	1	4.500	2.015	2.000	.829	.138	.412	1.353 $p < .02$	.691 $p < .01$
Weapons n = 36									
Total number of subsistants	3	20	8.000	7.000	4.485	.747	.561	1.158 $p < .02$	.756
Total number of technounits	3	83	29.861	26.000	18.551	3.092	.621	.930 $p < .02$	1.232 $p < .01$
Mean number of technounits per subsistant	1	7.750	3.811	3.667	1.571	.262	.412	.319	.919 $p < .01$
Tended facilities n = 36									
Total number of subsistants	2	25	10.500	9.500	6.381	1.063	.608	.729	.775
Total number of technounits	2	96	33.167	29.000	25.443	4.240	.767	1.192 $p < .02$	.731 $.05 > p > .01$
Mean number of technounits per subsistant	1	5.667	3.010	3.038	1.023	.170	.340	.286	.777
Untended facilities n = 36									
Total number of subsistants	0	34	8.306	6.500	7.989	1.331	.962	1.526 $p < .02$	.697 $p < .01$
Total number of technounits	0	157	40.083	28.000	41.978	6.996	1.047	1.413 $p < .02$	.733 $.05 > p > .01$
Mean number of technounits per subsistant[2]	1	7.929	4.462	4.636	1.507	.262	.338	.057	.726 $.05 > p > .01$

1. Vide footnote 1, table 2.
2. N is 33. The minimum number 1 is not the product of the division of total number of technounits by total number of subsistants given above. It refers to those societies which have untended facilities.

only, or even the best, explanation for the observed regional differences.

Moreover, the apparent relation may be spurious because it may be caused by an underlying relation between the variation in milieu and in the subsistence mode. This became clear when Oswalt introduced a further partitioning of the data, *i.e.* by milieu *and* economic mode. His relevant data are presented in table 8.

Because of the very small numbers, separate plots of the numbers of subsistants against those of the technounits have been omitted for these eight partitions. The relation between these two attributes in each of the eight partitions can be derived from figure 3. Also rank correlations do not yield the possibility to exceed a 5% probability of linearity, except for the tropical farming populations where linearity is extant ($r_s = 1.000$, $p < .01$). Performing Mann-Whitney U-tests on the full range of data for the eight groups produced results which suffered grossly from hyperprobability. The only tests which could achieve statistically significant differences were those run in combination with the tropics-farming societies (N=8). Of these, tropical farmers differed from desert farmers, as one would expect from the plots in figures 3d and 3e, and from arctic foragers, which were already discriminated from the tropics region in figure 4.

In Oswalt's third approach he proceeded from the four-fold taxonomy of subsistants, *i.e.* instruments, weapons, tended facilities and untended facilities. The numbers of subsistants and their constituent technounits are summed in all 36 societies for each of the four taxa. From these data, the

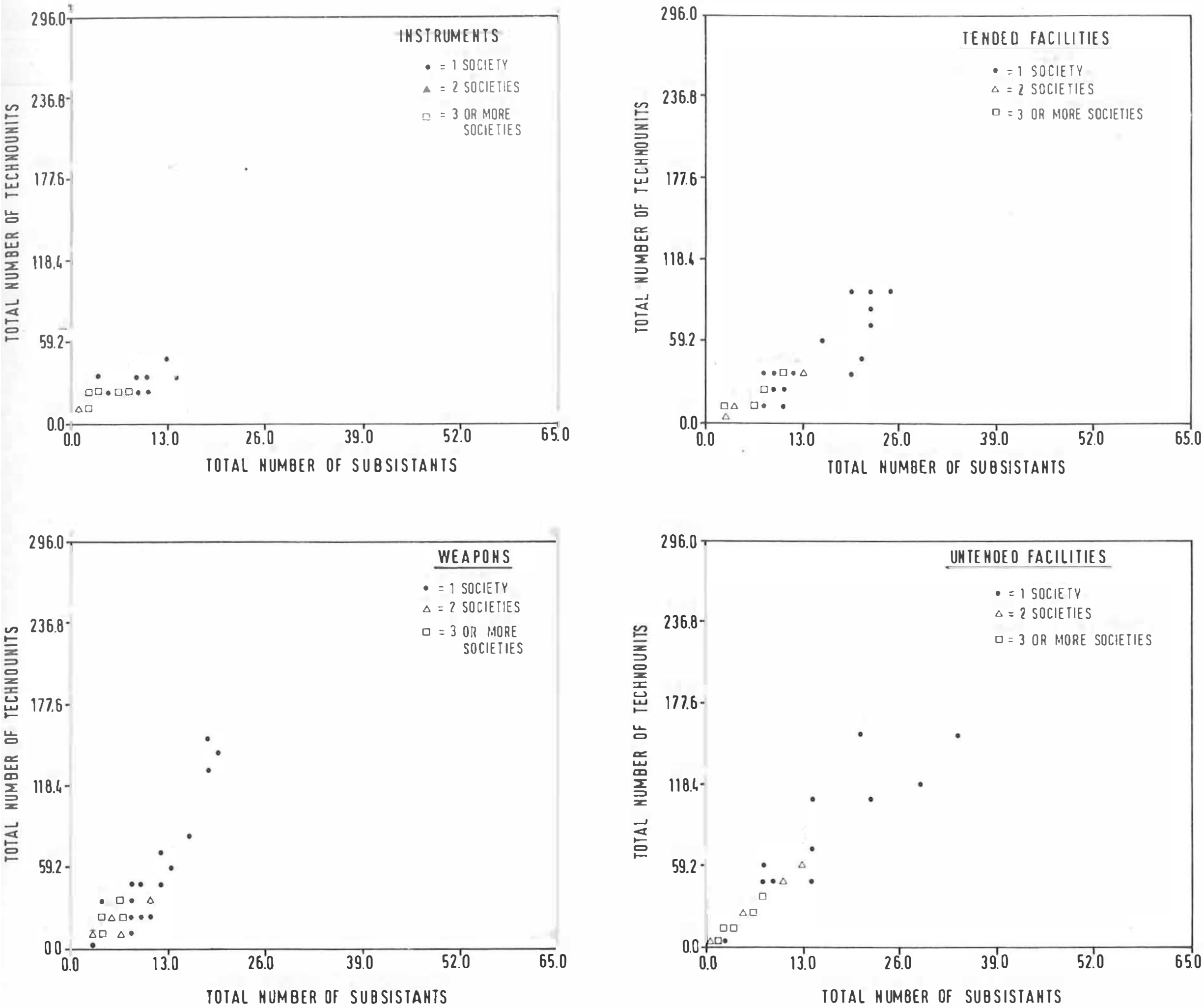


Fig. 5. Scattergrams of the total number of subsistants and the total number of technounits per society, partitioned by functional taxon.

mean numbers of technounits per subsistant in each taxon were derived (table 9).

Inspection of these data indicates that considerable sample bias is present when the data are partitioned by functional taxon. Most attributes show significant deviations in their skewness and kurtosis. These differences are also suggested by the numbers of subsistants/numbers of technounits relationships rendered in figure 5.

Within each taxon the linearity of the distribution was confirmed by significant Spearman rank correlation coefficients (table 10).

Mann-Whitney U-tests of the variation in technological complexity, as measured by the mean number of technounits per subsistant, between the four taxa by constituent society confirms the above impression of heterogeneity. The resulting grouping of the data is presented in table 11 and figure 6.

Two facts are evident from this analysis. Considerable distributional differences exist between the instruments and the tended facilities and between both of these taxa and the weapons and untended facilities. This demonstrates that it is incorrect to use the functionally unpartitioned samples in any analysis. Secondly a strong similarity between the distributions of the weapons and the untended facilities is indicated. This result would also indicate some measure of independence from the attribute milieu. The partitioning of the total sample into functional taxa does not provide a result which parallels that obtained in figure 4. A similar or correlated partitioning is only found when the instruments are analyzed separately (Appendix B). Only within the constraints of that one taxon do we

Table 10. Spearman rank correlations between the total number of subsistants and the total number of technounits in 36 societies, partitioned by functional taxon (Siegel, 1956).

	r_S	N	p
Instruments	.799	36	$<.001$
Weapons	803	36	$<.001$
Tended facilities	.926	36	$<.001$
Untended facilities	.980	33	$<.001$

Table 11. Mann-Whitney U-Test of the mean number of technounits per subsistant in 36 societies, partitioned by functional taxon (Siegel, 1956).

	Instruments N = 36	Weapons N = 36	Tended facilities N = 36	Untended facilities N = 33
Instruments	–			
Weapons	Z = 5.530 p < .0001			
Tended facilities	Z = 4.229 p < .0001	Z = 3.058 p = .002		
Untended facilities	Z = 5.886 p < .0001	Z = .709 p = .4778	Z = 4.283 p'< .0001	–

find a milieu-related partitioning. Viewed in terms of the whole functional range of our 36 societies, we find milieu to be a weak diagnostic attribute.

These results prove that the cumulative functional evolutionary hypothesis, proposed by Oswalt, is not valid and that it is necessary to look for another approach to interpret the observed variability.

Fig. 6. Statistical affinities of the distributions of the mean number of technounits per subsistant in 36 societies, partitioned by functional taxon.

3. THE RELATIONSHIP BETWEEN TECHNOLOGICAL DEVELOPMENT AND SOCIAL COMPLEXITY

From the foregoing it is clear that correlations with single variables such as economic mode or geographical region, without taking into account the distribution of the four taxa within each population, cannot explain the patterning of the data in a satisfactory manner. The data strongly suggest that the level of technological development of a society is better characterized by a measure which accounts for the functional diversity of its subsistence toolkit. Theoretical considerations lead to a similar conclusion. Tanner (1979) has proposed that studies of material culture which only address its technological content, *e.g.* Boserup (1981), Oswalt (1976), lead to incomplete insights into its background and significance. It is also necessary to consider its equally important and ethnically significant social and cultural context.

In addition to its properties of function and functional efficiency, each item of material culture also contains and carries with it certain elements of ethnically determined style (Jelinek, 1976; Sackett, 1968; 1977; Wobst, 1977). The context in which a tool is used is a reflection of the prevalent social needs and norms; *i.e.* when it is used, how it is used, by whom it is used, and who is its owner (De Boer & Lathrap, 1979; Giffen, 1930; Laumann & House, 1971; Lechtman & Merrill, 1975; Lustig-Arecco, 1972; Wiessner, 1983). An Athapascan birch bark basket and a Kwakiutl eulachon oil dish are functionally the same, *i.e.* containers. They are also morphologically similar. Although both show stylistic variation, examples of each which have the same number of technounits can be found. However, the social context in which each of them is used and the cultural value which is placed on each use is vastly different. What we must do is to examine the emic cognitions of function and social context in order to understand better the motivation and driving force behind technological change and progressive complexity. This requires a new approach in which a. the social factor is in some way measured and incorporated into the analysis and b. technological development is measured in such a way that its possible social relevance is demonstrable.

Such an examination can best begin by returning to the social dimensions and the functional and proprietary attributes of the four taxa of subsistants proposed by Oswalt. Both instruments and weapons are portable and potentially expedient subsistants which are made, used, and owned by individuals. They are also repaired and replaced by individuals. All appropriate members of the society have access to and use these subsistants on an individual basis. Both tended and untended facilities, on the other hand, are not or are considerably less portable. They are semipermanent or permanent fixtures in the landscape and represent a greater investment in time and energy than the fabrication of instruments or weapons (Binford, 1968; Stewart, 1978). Their location and placement in the landscape is done in mutual concert and consultation by a larger social and corporate unit than the individual household (Boas, 1966; Kroeber, 1955;

Stewart, 1978). Quite often such facilities are built and operated by such a larger unit and the harvest is shared. Moreover, fixed facilities demand a higher labour input in their manufacture, utilization, and maintenance (Anell, 1969). The increased complexity and higher level of energy input are rewarded by a considerably higher productivity than that yielded by a subsistence strategy based upon instruments and weapons alone. In short, the use of fixed facilities is the first step in the move from an extensive toward an intensive land-use system and economy (Binford, 1980; Bronitsky, 1979; Wiessner, 1982), which may also imply increased levels of sedentism. Such a move is a cultural choice which carries with it concomitants which must be accommodated within the cultural system.

In the first instance, it requires a greater number of active participants to build, exploit, and maintain the facilities, as well as to process their products. Secondly, it requires the development of a storage technology to preserve the short-term overproduction for subsequent use (Testart, 1982). Finally, and most importantly, it demands a higher level of leadership and cultural integration, coordination and cooperation. There must be some form of recognized authority which directs all of the above operations, which regulates and arbitrates the land-use, and which organizes the apportionment and re-distribution of the products of the joint effort. Because this system can represent considerable labour input and lead to the storage of large quantities of potentially portable food, territorial defence, defence of the facilities, and protection of the stored produce may need to be organized as well.

In short, we find that progression from an extensive to an intensive land-use system, based upon increasing reliance on fixed facilities, is a complex self-feeding system. Such a system can only develop when there is an increasing social complexity, increasing technological complexity, and increasing reliance upon the interdependence of these factors. Increases in population size and density are concomitant to the above. Looked at in this light, the transition from a foraging economic mode to one based upon farming is but a difference of degree, not of kind. The historical record is clear that the mainstream of human society moved successfully along this evolutionary progression. However, it is instructive to realize that such a progression was not inevitable and that it is a question of cultural choice, whether a particular society moved along that scale of progressive change or not. In the ethnographic record there are numerous examples of societies which have lived in proximity to other societies which have embarked upon a more complex technological, economic and social system. Despite culture contact, the former societies have chosen to retain their simpler pattern, *e.g.* Labrador Inuit (Taylor, 1974; 1975), northeastern Algonkian tribes (Rostlund, 1952), Kutchin Athapascans (McKennan, 1965), *etc.* The failure of agriculture to be adopted by a large number of Indian societies in the western and northwestern parts of North America may also be seen as cultural choice. The same can be said for the tardiness with which food production was adopted in western and northwestern Europe.

In view of the above, we decided that the *percentage of facilities* of the total number of subsistants should be used as an indicator of technological/social development of a society, rather than the mean number of technounits per subsistant. Proceeding on the foregoing premises, we tried first to increase the data resolution by testing the percentage of facilities according to the foregoing analytical algorithm. None of the results led to a satisfactory demonstration of the inter-relationship between technological complexity and technological development. The *prima facie* correlation with the milieu (mean annual temperature), observed for the mean number of technounits per subsistant (note 3, *vide* also pp. 7-9) was not extant for the percentage of facilities ($r_s = -.117$ $p > .20$). This can only lead to the conclusion that the attributes and partitions chosen by Oswalt to demonstrate these processes of development are inappropriate and/or are cross-culturally invalid. Clearly a different combination of attributes is needed.

Following Carneiro (1967; 1974), we then took population density as a rough measure of social integration and complexity and tested same against the following variables: 1. mean number of technounits per subsistant, 2. percentage facilities of the total number of subsistants, and 3. milieu, among those societies for which we have reliable and mutually comparable population density data. The data derived from Oswalt, our density figures (Newell & Constandse-Westermann, in prep.), and the relevant Spearman rank correlation coefficients are presented below (table 12).

At face value, none of these correlations is particularly striking. Only that between the percentage of facilities and milieu ($r_s = .600$) achieved the .05 level of significance and we have already seen that milieu is a difficult variable to interpret alone. The expected correlation between population density and percentage of facilities produced a disappointing .250. However, in all but one of the correlations, *i.e.* that between the population density and the mean number of technounits per subsistant ($r_s = .021$), the deviation from a hypothetical linear relationship was not spread equally through all cells. Instead, two of the nine tribes accounted for most of that deviation. Both the Ingalik and the Upper Tanana were anomalous. If these two are re-

Table 12. Analysis of the technological and social complexity of nine North American Indian and Inuit societies.

Tribe name	Total number of subsistants	Total number of technounits	Mean number of technounits	Total number of instr./weap.	Total number of facilities	Percent of facilities	Population density	Milieu rank[1]
Twana	48	237	4.9	16	32	67	.292	3
Ingalik	55	296	5.4	19	36	66	.018	2
Upper Tanana	25	105	4.2	9	16	64	.010	2
Klamath	43	151	3.5	16	27	63	.094	3
Yakutat	28	121	4.3	12	16	57	.127	3
Copper Eskimo	27	122	4.5	12	15	56	.024	1
Kakligmiut	35	205	5.9	19	16	46	.171	1
Iglulik	42	225	5.4	23	19	45	.007	1
Tanaina	40	224	5.6	23	17	43	.022	2

Spearman rank correlation (Siegel, 1956): p = .05

	Population density	Percent facilities	Mean number of techno-units	Milieu
Population density	–			
Percent facilities	.250			
Mean number of technounits	–.021	–.479		
Milieu	.450	.600	–.471	–

1. Rank 1 = Arctic, Rank 2 = Sub-Arctic, and Rank 3 = Temperate

moved from the analysis, the following table obtains (table 13).

Comparing these results with table 12, it is clear that all relationships are strengthened, except that between population density and the mean number of technounits per subsistant, which remained almost the same, *i.e.* -.021 to -.071. The most striking change is that of the correlation between population density and the percentage of facilities, *i.e.* from .250 to .714. This correlation now attains significance at the .05 level. The correlation between the percentage of facilities and milieu was increased, *i.e.* from .600 to .714, attaining the same significance level as the foregoing correlation *i.e.* $p = .05$. The negative correlation $r_s = -.479$ between percentage of facilities and the mean number of technounits per subsistant is strengthened to -.679, indicating the lack of fit between these two variables, and consequently, the inappropriateness of the latter as a measure of technological development. Obviously the relation with milieu, which did not obtain on a world-wide scale (*vide* p. 7) is strengthened when the area of investigation is limited to a few major geographic regions.

Were it not for the two anomalous societies, the .714 correlation would be indicative of a strong relationship between population density, as a measure of social complexity, and the percentage of facilities, as a measure of functional complexity and extractive efficiency. At face value, the density figures for both the Ingalik and the Upper Tanana Athapascans are far below those which we would expect from their percentage of facilities figures, *i.e.* 66% and 64%. However, if we again hold milieu constant and take the cultural context into consideration, we see that the Ingalik had the highest population density of all Athapascan tribes in the Yukon-Kuskokwim drainage and that the Upper Tanana had the second highest value for all Cordilleran interior tribes. Looked at in this light, we would suggest that these two tribes attained such relatively high densities because of their high percentage of facilities and that their low absolute densities were a function of the milieu in which they

Table 13. Analysis of the technological and social complexity of seven North American Indian and Inuit societies. Spearman rank correlation (Siegel, 1956): p = .05.

	Population density	Percent facilities	Mean number of techno-units	Milieu
Population density				
Percent facilities	.714			
Mean number of techno-units	–.071	–.679		
Milieu	.500	.714	–.500	–

lived. Therefore, these two apparent anomalies do conform to the thrust of the hypothesized linear relationship, but not at the same level, *i.e.* they support the principal of the correlation, but not at the same scale as the rest of the seven societies.

From the foregoing, we would maintain that the relationship between the complexity of the social component of technology, as reflected by the percentage of facilities, and of the social organization, reflected by population density, obtains. The rank correlations do not attain the .01 level of probability, but the direction and level of their change when comparing tables 12 and 13 give a clear indication to that effect. Furthermore we propose that this relationship is also a reflection of the milieu, because that variable is the context within which the interaction between technology and socio-cultural phenomena takes place. The range of resource opportunities offered by the milieu made the use of fixed facilities attractive. This latter contention is in fact demonstrated by the above 'anomaly' of the Ingalik and the Upper Tanana. Cultural choice and social institutions allow the available technology to work in any specific milieu, including such marginal situations as those of these two seemingly anomalous societies. The explanation of the connection between milieu and population density must be sought in the ecological influence on the resource basis *and* on the development of cultural institutions which permit the adoption and utilization of functionally complex subsistence technologies. The existence of such a connection has already been demonstrated in our demographic research of the North American Indian hunting and gathering societies (Newell & Constandse-Westermann, in prep.).

Returning to Oswalt's analogous sample, a few concluding remarks are in order. The unsatisfactory resolution of the first set of analyses is due to the fact that the mean number of technounits per subsistant is not a particularly diagnostic variable. The defined technological complexity does not provide a clear indication of any evolutionary trends or of their causation. Furthermore, while 'milieu' is an important variable, our analyses have demonstrated that, in the present context, it is not the dominant variable which can explain the evolution of technology. The proposed evolutionary trend inherent in subsistant equipment only becomes explicable when we re-cast the data in such a way that the socio/cultural context of technology, in articulation with the milieu (and its resources), is available for analysis. When this is done, we find an indivisable triangle of inter-relationships which has the potential of evolutionary progress, *i.e.* an increasing functional complexity, increasing population density, and an increasing intensity of utilization of the milieu (= greater production). However, the pursuit and attainment of this complex relationship is a matter of cultural choice. Alternatives to increasing production and attaining higher levels of social organization, including cultural extinction, are always available (Bockstoce, 1973). In the following evaluation of the Western European Mesolithic, this same range of responses to technological, economic, environmental, and social stimuli must be born in mind.

4. TECHNOLOGICAL DEVELOPMENT AND SOCIAL COMPLEXITY IN THE WESTERN EUROPEAN MESOLITHIC

An ongoing study of Mesolithic subsistence equipment has indicated an increase in its range and complexity as well as a trend toward more passive, fixed facilities (Newell & Andersen, in prep.). Through the course of the period there is also evidence for changes in the level of social organization. Archaeological data suggest that the Mesolithic societies of Western Europe were organized largely at the band level of social organization (Newell *et al.*, in prep.). A detailed study of the demography of 256 analogous subarctic and temperate North American Indian hunter-fisher-gatherer societies indicated a similar level of social organization (Newell & Constandse-Westermann, in press, in prep.; Newell *et al.*, in prep.). As such, most Mesolithic and North American hunting-fishing-gathering populations are clearly discriminated from fully agricultural/pastoralist groups, the large majority of which is organized at the tribal, or even at the chiefdom level. Clinal deviations from this pattern have been observed among some North American societies (Driver, 1969; Heizer, 1978; Kenyon, 1980; Martin, 1974; Sahlins, 1968; Service, 1971; Suttles, 1968). A similar clinal transition to a higher level of social integration and sedentism in some societies appears to characterize the closing phase of the Western European Mesolithic (de Langen, n.d.). These changes are related to a measured intensification of territoriality, *i.e.* a progressive decrease of the size of the territorial units (van Holk & de Roller, n.d.; Newell *et al.*, in prep.).

To obtain insight in the development of population density in the Western European Mesolithic we examined principles and processes of population dynamics (Constandse-Westermann & Newell, 1984, in press) and compared those results with the demographies of our analogous Indian societies. That comparison demonstrated that the above changes in the level of social organization are concomitant with an increase in population numbers, population density, and possibly also in population growth (Newell, 1984; Newell & Constandse-Westermann, in press). Our Mesolithic growth and density figures attain the same order of magnitude as that proposed for the Neolithic of the Near East by Carneiro & Hilse (1966). Such changes are made possible by the coordinated investment of greater labour input and land improvements in the form of fixed facilities, greater social integration and leadership, and the development of a storage technology (Testart, 1982). Food storage in the Western European Mesolithic is a subject which has been totally ignored to date. However, in his discussion of the theoretical aspects of food storage with specific reference to hunting societies, Ingold (1983) states that delayed return systems of production are prevalent in the majority of contemporary hunter-gatherer societies.

All the other parts of the equation seem to be extant or at least sufficiently well documented that we may propose that the transition from a Mesolithic (foraging) economy and society to a Neolithic (farming) economy and society was not as abrupt as we have been lead to believe (Childe, 1951). Instead, the process of intensification of land-use and its social concomitants had started already before the introduction of food production took place. The study of the process of intensification of land-use would seem to be a more fruitful line of inquiry than that of technological complexity, as proposed by Boserup (1981) and Oswalt (1976).

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The main thrust of this paper stems from lectures given by the first author in Cultural Anthropology for prehistorians at the Biologisch-Archaeologisch Instituut. On the occasion of the visit of Dr. E. Boserup to the State University of Groningen in October 1983, the *Economische Faculteit* and the *Subfaculteit Prehistorie* organized a joint symposium: Reflections on Population and Technological Change. This symposium was held between 12 and 13 October 1983. Because of the nature and thrust of our joint work, we were approached by Prof. Dr. J.D. van der Waals, one of the co-organizers, with a request that we present a prehistoric perspective to the issues presented in Dr. Boserup's latest book, currently of interest to development economists and demographers specializing in Third World problems.

As the original publication plans apparently could not be realized, we seized the opportunity to expand upon our Symposium paper and make the content of our continuing collaboration available to both our students and to a wider, more informed public. In that endeavour we were supported by Prof. van der Waals, who commented on an early draft and arranged its inclusion in *Palaeohistoria*. Subsequent drafts were read and criticized by Ms. M.E.N. Aarts and Mr. D. Kielman.

The drawings were made by Mr. J. Dijkema of the Biologisch-Archaeologisch Instituut and Ms. H. Klaassens typed the final version of the manuscript.

6. NOTES

1. Viewed in terms of Oswalt's hypothesis, both axes of the scattergram represent underlying continua of complexity, one expressed as subsistants and the other as technounits. The relevant variables of his 36 societies can be ordered along these scales. Therefore, as long as we are testing or working within the proposed linearity of Oswalt's original hypothesis, the subsistant and technounit counts per society may be seen as ranks or ordinal data along the two underlying continua. Within these constraints, the appropriate test for linearity is the Spearman rank correlation coefficient.
   The Pearson product-moment correlation coefficient cannot be used here due to the ordinal nature of the data and because they are not normally distributed.
   All rank correlations between the number of subsistants and the number of technounits per society in the various partitions have been tested one-tailed because H• states that these two numbers will increase together, *i.e.* positive correlation. The decision level on all statistical tests is taken to be .01 or less. This is because of the sample size and the obvious lack of uniform representation along the nominally partitioned ordinal continua. In order to reduce the risk of a type II error due to incomplete data, we have opted for a strict decision level (Siegel, 1956).
2. The results of most Mann-Whitney U-tests have been tested two-tailed because there was no expectation of direction in the variation of complexity. Only in the case of the partitioning by economic mode have we tested one-tailed, due to Oswalt's explicit hypothesis that technological complexity will be greater in farming than in foraging societies.
3. Oswalt's five-fold division is apparently based upon Köppen's (1931) climatic zones. Because Köppen mixed variables in his descriptive definitions of each zone, we have examined a number of relevant attributes for the milieu occupied by each of Oswalt's 36 societies. A significant correlation between mean annual temperature and mean number of technounits per subsistant was obtained ($r_s = -.556$, $p < .001$). Soil type, length of growing season, and evaporation rate followed the same ordinal scale from arctic to tropics. Mean annual rainfall was not consistent with the above continua, *i.e.* $r_s = .034$, $p > .20$. Other factors, *e.g.* natural vegetation, terrain and relief were also inconsistent with the underlying continuum, suggested by Köppen and utilized by Oswalt. More importantly, none of the above are strictly independent variables, but rather are constituents of a more complex and variable entity, the ecosystem (Ødum, 1971). In terms of this analysis, we will refer to 'milieu', denoting the four attributes, and their inter-relations, which are consistent with Köppen's original ordinal scale.

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APPENDIX A: Basic data (from: Oswalt, 1976).

Society	Instruments			Weapons			Tended facilities			Untended facilities			Total		
	no. subs.	no. techn.	mean techn.	no. subs.	no. techn.	mean techn.	no. subs.	no. techn.	mean techn.	no. subs.	no. techn.	mean techn.	no. subs.	no. techn.	mean techn.
Arctic, foragers															
Copper Eskimos	4	16	4.0	8	53	6.6	11	36	3.3	4	17	4.2	27	122	4.5
Iglulik	3	8	2.7	20	142	7.1	8	27	3.4	11	48	4.4	42	225	5.4
Tareumiut	1	3	3.0	18	133	7.4	10	41	4.1	6	28	4.7	35	205	5.9
Angmagsalik	4	18	4.5	18	151	8.4	9	20	2.2	2	13	6.5	33	202	6.1
Subarctic, foragers															
Caribou Eskimos	3	12	4.0	10	39	3.9	13	37	2.8	8	30	3.8	34	118	3.5
Nabesna	1	1	1.0	8	36	4.5	8	23	2.9	8	45	5.6	25	105	4.2
Ingalik	6	14	2.3	13	64	4.9	15	61	4.1	21	157	7.5	55	296	5.4
Tanaina	7	13	1.9	16	83	5.2	3	17	5.7	14	111	7.9	40	224	5.6
Temperate, foragers															
Tasmanian	3	3	1.0	3	3	1.0	4	8	2.0	1	1	1.0	11	15	1.4
Klamath	9	18	2.0	7	35	5.0	22	70	3.2	5	28	5.6	43	151	3.5
Tlingit	4	7	1.8	8	25	3.1	8	34	4.2	8	55	6.9	28	121	4.3
Twana	4	7	1.8	12	70	5.8	19	96	5.1	13	64	4.9	48	237	4.9
Temperate, farmers															
Huron	6	12	2.0	4[1]	13[1]	3.2	11	26	2.4	6	20	3.3	27	71	2.6
Aymara	10	28	2.8	8	15	1.9	22	91	4.1	7	19	2.7	47	153	3.3
Ojibwa	8	13	1.6	10	32	3.2	10	33	3.3	9	43	4.8	37	121	3.3
Lepcha	13	32	2.5	12	49	4.1	11	33	3.0	29[1]	116	4.0	65	230	3.5
Desert, foragers															
Surprise Valley Paiute	7	15	2.1	9	27	3 0	19	41	2.2	4	14	3.5	39	97	2.5
Aranda	4	7	1.8	4	21	5.2	7	10	1.4	1	4	4.0	16	42	2.6
Naron	2	5	2.5	5	19	3.8	3	5	1.7	2	11	5.5	12	40	3.3
Owens Valley Paiute	4	9	2.2	9	44	4.9	10	30	3.0	5	24	4.8	28	107	3.8
Desert, farmers															
Pima	7	1	1.6	4	13	3.2	3	7	2.3	3	5	1.7	17	36	2.1
Walapai	14	18	1.3	7	36	5.1	10	17	1.7	4	12	3.0	35	83	2.4
Hopi	7	12	1.7	6	12	2.0	8	11	1.4	14	49	3.5	35	84	2.4
Yuma	3	3	1.0	5	18	3.6	4	14	3.5	2	8	4.0	14	43	3.1
Tropics, foragers															
Tiwi	3	6	2.0	6	6	1.0	2	2	1.0	–	–	–	11	14	1.3
Ingura	3	3	1.0	6	19	3.2	3	8	2.7	1	2	2.0	13	32	2.5
Chenchu	7	13	1.9	7	26	3.7	6	16	2.7	–	–	–	20	55	2.8
Andamanese	4	8	2.0	4	31	7.8	3	12	4.0	–	–	–	11	51	4.6
Tropics, farmers															
Jivaro	4	6	1.5	4	19	4.8	6	16	2.7	2	10	5.0	16	51	3.2
Trukese	8	12	1.5	4	8	2.0	22	78	3.5	8	38	4.8	42	136	3.2
Pukapuka	9	9	1.0	3	10	3.3	25	95	3 8	8	30	3.8	45	144	3.2
Kapauku	11	16	1.5	6	23	3.8	8	28	3.5	10	47	4.7	35	114	3.3
Naga	8	14	1.8	4	24	6.0	13	35	2.7	13	59	4.5	38	132	3.5
Akamba	8	15	1.9	7	41	5.9	21	45	2.1	14	76	5.4	50	177	3.5
Tanala	6	11	1.8	10	26	2.6	9	32	3.6	22	106	4.8	47	175	3.7
Tonga	5	9	1.8	3	9	3.0	12	39	3.2	34	153	4.5	54	210	3.9

1. Corrected figure, see Oswalt, table 9-2 vs. pp.269-270 and 276-278.

APPENDIX B

Mann-Whitney U-test of the mean number of technounits per subsistant in 36 societies, partitioned by economic mode, per functional taxon.

	Foragers/Farmers			
Instruments	n = 20	n = 16	u = 88.0	.025 > p > .010
Weapons	n = 20	n = 16	u = 142.5	p > .050
Tended facilities	n = 20	n = 16	u = 157.5	p > .050
Untended facilities	n = 17	n = 16	u = 89.0	p = .050

Mann-Whitney U-test of the total number of subsistants in 36 societies, partitioned by geographic region

Arctic	—				
Subarctic	u = 7.0 p = .886				
Temperate	u = 11.5 .570 > p > .460	u = 15.0 p = .934			
Desert	u = 9.0 p = .282	u = 7.0 p = .154	u = 16.5 .130 > p > .104		
Tropics	u = 23.0 p > .100	u = 19.0 p > .100	u = 39.5 p > .100	u = 35.5 p > .100	—
	Arctic n = 4	Subarctic n = 4	Temperate n = 8	Desert n = 8	Tropics n = 12

Mann-Whitney U-test of the total number of technounits in 36 societies, partitioned by geographic region

Arctic	—				
Subarctic	u = 7.0 p = .886				
Temperate	u = 10.0 p = .386	u = 14.0 p = .808			
Desert	u = 0.0 p = .004	u = 1.0 p = .008	u = 12.0 p = .038		
Tropics	u = 8.0 .100 > p > .050	u = 13.0 p > .100	u = 36.0 p > .100	u = 28.0 p > .100	—
	Arctic n = 4	Subarctic n = 4	Temperate n = 8	Desert n = 8	Tropics n = 12

Mann-Whitney U-tests of the mean number of technounits per subsistant in 36 societies, partitioned by geographic region, per functional taxon

Instruments					
Arctic	–				
Subarctic	u = 2.5 .200 > p > .114				
Temperate	u = 1.0 p = .008	u = 13.5 .808 > p > .682			
Desert	u = 0.0 p = .004	u = 11.5 .570 > p > .460	u = 26.5 .646 > p > .574		
Tropics	u = 0.0 p = .002	u = 14.5 p > .100	u = 33.0 p > .100	u = 41.5 p > .100	–
	Arctic n = 4	Subarctic n = 4	Temperate n = 8	Desert n = 8	Tropics n = 12

Weapons					
Arctic	–				
Subarctic	u = 4.0 p = .342				
Temperate	u = 13.0 p = .682	u = 8.0 p = .214			
Desert	u = 10.0 p = .368	u = 9.0 p = .282	u = 25.5 .574 > p > .506		
Tropics	u = 17.0 p > .100	u = 14.0 p > .100	u = 41.5 p > .100	u = 46.0 p > .100	–
	Arctic n = 4	Subarctic n = 4	Temperate n = 8	Desert n = 8	Tropics n = 12

Tended facilities					
Arctic	–				
Subarctic	u = 7.0 p = .866				
Temperate	u = 15.0 p = .934	u = 15.0 p = .934			
Desert	u = 5.0 p = .072	u = 4.0 p = .048	u = 9.5 .020 > p > .014		
Tropics	u = 20.0 p > .100	u = 12.0 p > .100	u = 38.0 p > .100	u = 21.5 .050 > p > .020	–
	Arctic n = 4	Subarctic n = 4	Temperate n = 8	Desert n = 8	Tropics n = 12

Untended facilities					
Arctic	–				
Subarctic	u = 5.0 p = .486				
Temperate	u = 13.0 p = .682	u = 6.0 p = .110			
Desert	u = 6.0 p = .110	u = 4 0 p = .048	u = 27.0 p = .646		
Tropics	u = 17.0 p > .100	u = 7.5 p > .100	u = 35.0 p > .100	u = 22.0 p > .100	–
	Arctic n = 4	Subarctic n = 4	Temperate n = 8	Desert n = 8	Tropics n = 9