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HAWAIIAN ACTIVITY SETS: INITIAL RESULTS OF R-MODE MULTIVARIATE STATISTICAL ANALYSES

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This paper presents initial results of R-mode multivariate statistical analyses done in Spring 1974 which indicate possible "activity sets" (a set of tools used for the same activity) in the Hawaiian archaeological record. A more detailed preliminary report is on file at the Department of Anthropology (University of Hawaii); here initial results are briefly noted. Twenty functional artifact types were recorded for 65 assemblages using raw counts, and artifact types which grouped together consistently across assemblages were revealed using Pearson's r as the correlation coefficient and different multivariate techniques (factor analysis, principal components analysis, complete-link cluster analysis, and smallest space analysis). By using only functional artifact types, it was expected that resulting groupings would be controlled to an extent to reflect functional dimensions and thus more readily reflect possible activity sets. (This procedure is acceptable according to Doran 1970: 63-4; Hill and Evans 1972: 250; and Sackett, 1973). Initial results show similar groupings revealed by all analyses.

DATA

Here an assemblage is defined as the set of artifacts from one temporal component within an archaeological site. The 65 assemblages analyzed include published and unpublished assemblages from Oahu, Maui, and Hawaii; from upland and coastal sites; and from cave and open sites. All assemblages are ca 200-400 years in time span (determined by either dated cultural stratigraphic layers or arbitrary levels). Also in all but two cases (Koaie village of Lapakahi and 018) assemblages represent those of one architectural structure. This is done for a number of reasons such as ethnohistorical documentation of different activities in different structures and problems of proving contemporaneous use of adjacent structures.

The 20 functional artifact types follow common usage in Hawaiian archaeology with a few slight alterations. Fishhooks are divided into "bonite hooks" (points and lure-shanks), "other hooks", and "blanks" (associated with "other hooks"). Finer functional divisions of "other hooks" probably occurred, but are unknown presently. Also all adzes, adze chips, adze blanks are placed under "adze" although again several yet unknown functional types may have existed. No uniform functional typology exists for stone abrading tools (a task which needs to be done as ethnohistory indicates some were used for woodworking and others for fishing gear manufacture), so all stone abrading tools are lumped under "abrader". Finally, used and unused volcanic glass are combined under "volcanic glass". The remaining types are straightforward and appear in the figures accompanying the text.

RESEARCH DESIGN AND MULTIVARIATE TECHNIQUES USED

As different multivariate methods used to discover groupings within a set of data yield slightly different results (cf Hodson, 1969, 1970; Hodson *et al.*, 1966; Tainter, 1973, 1974), the best approach to grouping analyses was seen to be the use of several methods and the comparison of the results. The techniques used here were factor analysis, principal components analysis, a polythetic agglomerative cluster analysis (Johnson's maximal or complete-link), and smallest space analysis. In all cases, correlation matrices were computed using Pearson's r.

The factor analysis used is the PA2 programme in the SPSS package (Nie, Bent and Hull, 1970: chap. 17). This is a "classical" factoring procedure with iteration. Varimax orthogonal rotation was used. Factors of eigenvalue less than 1.0 were not utilized. The principal components analysis used also comes from the SPSS package - being listed as PA1 under factor analysis (*Ibid.*, chap. 17). PA1 is without iteration. Varimax orthogonal rotation was again used. The polythetic agglomerative technique used was S. Johnson's (1967) maximal (complete-link) cluster analysis which was set up in programme format for the DON (Development of Nations) Project by Charles Wall (Aloha Systems, University of Hawaii). This is one of the most common cluster analyses and gives out realistic results (cf. Johnson, 1967). The smallest space analysis (SSA) is that of the Guttman-Lingoes package of nonmetric programmes listed as D-SSA1 at the University of Hawaii.

Three problems relevant to the analysis should be noted here. First, a large number of 0-0 observations (an artifact type not present in either of two assemblages) were present which will affect the correlation matrix. When using Pearson's r, strong negative correlations become weak and the number of weak positives increase in the matrix (Spoth and Johnson, 1974). A solution to this problem has been offered when missing data are not present (Tainter, 1973; 1974, personal communication). Missing data are present, however, and thus the reader should be forewarned to expect few strong negatives.

The second problem involved how to treat missing data (which were not numerous but present in a few assemblages). In the initial runs using factor analysis, two SPSS options were alternately used to check result differences (cf. Nie, Bent and Hull, 1970: chap. 17). A default option (hereafter called "no options) eliminates the case (assemblage) containing missing data from the analysis. Option 2 eliminates only the missing data. It was found that each option yielded some groupings which differed (as will soon be seen).

In addition to missing data problems, it seemed as if artifact counts per assemblage might skew results, for many assemblages had only a few artifacts and a few assemblages had large amounts of volcanic glass and few other artifacts. To check this possible problem, three different assemblage samples were run and compared for groupings. One sample took all 65 assemblages regardless of number of artifacts per assemblage. Another took only assemblages with 20 or more artifacts (44 assemblages). The last sample took only assemblages with 20 or more artifacts other than volcanic glass (30 assemblages). Factor analysis and principal component analysis runs of each of these three samples revealed almost no differences between the different samples' groupings.

GROUPING RESULTS

Results are shown in Figures 1-4.

Factor Analysis

Figure 1 indicates the high and moderate loadings for artifacts on the factors for No Options and Option 2, respectively. The value .30 was chosen as the lowest range of moderate loadings. Artifacts scoring higher than .30 on each factor are analyzed. No negative loadings greater than -.30 were present and very few were above -.20. Use of No Options agrees in all samples on the following groupings:

Factor 1 - Bonito hooks, chisels (moderate scores on worked shell and drills)

Factor 2 - Picks (moderate - echinoid abraders)

Factor 3 - Sinkers

Factor 4 - Volcanic glass, worked bone, octopus lures, "other" fish-hooks, fish-hook blanks, awls, stone abraders, echinoid abraders

Disagreement occurs in how to handle adzes, basalt flakes, poi pounders, and grater/scrapers. Option 2 produces the following groupings for all three samples:

1 - Sinkers, bonito hooks, basalt flakes, octopus lures (moderate - awles)

2 - Worked bone, volcanic glass (moderate - tattoo needles and awls)

3 - Worked shell and chisels (moderate - tattoo needles)

4 - Grater/scrapers, ulumaika stones, poi pounders (moderate - awls)

5 - Picks, fish-hooks, fish-hook blanks, stone abraders, echinoid abraders, drills.

Principal Components Analysis

Principal components analysis (which Blacklith and Royment, 1971: 204, claim is a better method than factor analysis or cluster analysis due to less flaws and more theoretical soundness) reveals exactly the same groupings as factor analysis under No Options and Option 2. Figure 2 illustrates the dominant artifacts scoring above .30 on each principal component (high, moderately high, and moderate scores are separated by dotted lines). The groups are much clearer here as scores are higher.

Complete-Link Cluster Analysis

Johnson's hierarchical cluster analysis (complete-link) was done for a 30-assemblage size sample with a No Options matrix. The dendogram is presented in Figure 3a. In cluster analyses one chooses a cut-off (termination) point and looks at the clusters or groups formed at that point. Often a cut-off point is chosen by viewing the curve of similarity values of each successive agglomerative step and selecting the point prior to marked steepening in the curve. The clusters formed at this point are assumed to best maximize the degree of differences between clusters while still minimizing the degree of internal differences (cf. Tainter, 1973: 65). Figure 3b illustrates such a point after 11 agglomerations, and this is where the groupings at line 1 occur in Figure 3a. Clusters formed at this point are:

Cluster 1 - Tattoo needle, pick, ulumaika stones, poi pounder

Cluster 2 - Volcanic glass, worked bone, echinoid abraders, hooks, hook blanks, awls, octopus lures

Cluster 3 - Sinker

Cluster 4 - Grater/scrapers

Cluster 5 - Adze, basalt flakes

Cluster 6 - Chisels, bonito hooks, drills, worked shell

These latter groups (except for Cluster 1) match those of factor analysis and principal components analysis at the 30-assemblage sample with No Options exactly.

INTERPRETATIONS

It will be recalled only functional artifact types were used in this analysis in the hopes of biasing resulting groups into those of functionally related tools or activity sets. This seems to have worked. The factor analyses, principal components analyses, and complete-link cluster analysis (at the 11th agglomeration) using a No Options matrix all agree on two basic groups of artifacts -

(1) volcanic glass worked bone, abraders, echinoid abraders, hooks, hook blanks, awls, octopus lures; and

(2) bonito hooks, chisels, worked shell, and drills.

I would interpret these as two different fishing and fishing-gear manufacturing kits. The first kit utilizes bone as its raw material, and the worked bone and fish-hook blanks reflect the conversion stages of this raw material to the finished artifact (the hook). The volcanic glass is suggested to have been used to cut the bone in the initial manufacturing stages (as seen in its association with worked bone and echinoid abraders in a sub-cluster of high similarity value, .90, at agglomeration 3 in the complete-link analysis). This proves interesting for, although volcanic glass is a frequently occurring artifact in Hawaiian sites, its function is virtually unknown. The ethno-history does not mention their use. Edge-wear analysis has been rare (e.g., Newman, 1970, with unreported results; Barrera and Kirch, 1973). Barrera and Kirch (1973: 185) suggest edge-wear of the Halawa Valley volcanic glass indicates "scraping and chopping functions". They opt for food preparation or delicate woodworking as the function of the volcanic glass, but this analysis suggests working of bone material. Abraders (stone and echinoid) are suggested to have been used in later finishing stages (agreeing with Emory, Bonk and Sinoto, 1959). Awls' function are unknown, and octopus lures' occurrence with this kit is unaccounted for.

The second fishing/fishing-gear manufacturing kit suggests a special bonito fishing and bonito hook manufacturing activity centred about the use of shell as a raw material. Here worked shell reflects conversion stages of the raw material with drills and chisels the tools for working the shell. While drills are an accepted tool for such work (Emory, Bonk and Sinoto, 1959), chisels have never to my knowledge been suggested for shell work. I would suggest chisels were used for the initial rough cutting of the shell. (The strength of this kit seems to be further attested to by the co-occurrence of bonito hooks and chisels at the first agglomeration of the cluster analysis).

The other artifacts with techniques using the No Options matrix do not cluster or are not consistently clustered. Part of this may be due to the low numbers of artifacts. Only eight tattoo needles, 10 ulumaika stones, and 10 poi pounders occur throughout all 65 assemblages. It is suggested they be deleted for that reason. Picks, sinkers, graters/scrapers, adzes, and basalt flakes provide other problems for they occur singly in separate groupings (occasionally adzes and basalt flakes are paired). Are they catch-alls or do they have some functional meaning? Picks have been noted as mollusc extraction devices in the past, adzes as a woodworking tool, and graters/scrapers as a food preparation tool. Sinkers are documented as part of an octopus fishing device along with octopus lures (cf. Emery, Bonk and Sinoto, 1959).

Techniques using Option 2 matrices support the above interpretations. Here four groups are yielded:

(1) bonito hooks, octopus lures, sinkers, basalt flakes (awls moderately);

(2) worked shell and chisels;

(3) worked bone and volcanic glass; and

(4) hooks, hook blanks, abraders (stone and echinoid), and drills.

The first two groups reflect the bonito tool kit (or shell-focused kit) and the latter two groups the "other" hook tool kit (or bone-focused kit). In the case of the bonito hook kit, octopus lures, sinkers and basalt flakers are added and drills dropped. The co-occurrence of octopus lures and sinkers matches ethnographic data which record them as part of of one finished artifact - the octopus fishing hook. The presence of basalt flakes is not disturbing, and it is suggested they may represent early cutting stages of shell manufactur. The dropping of the drills is unexplained, as is the presence of awls. Chisels and worked shell again co-occur adding credence to the hypothesis that chisels were used in initial cutting stages of shell work. The "other" hook kit is little altered except for the addition of drills which are postulated to have been used for bone working as well as shell. The use of volcanic glass for initial cutting of the bone material is again re-emphasized by the isolation of these two artifact types as a group.

Graters/scrapers form an additional single group under Option 2 matrices if ulumaika stones and poi pounders are deleted as suggested above.

SMALLEST SPACE ANALYSIS

This is an appropriate time to look at the smallest space analysis as a visual picture of the above groupings can be clearly seen. Figure 4 presents results at 1-, 2-, and 3-dimensions for a 30-assemblage sample using a No Options matrix. (Results would be slightly different if an Option 2 matrix were used as seen in the above discussions.) Tattoo needles, ulumaika stones, and poi pounders are deleted for reasons noted above. Figure 4a indicates results on one-dimension. Here the artifacts' characteristic of the postulated "other" hook activity set occur to the left of -20 with the addition of sinkers (hook blanks are at -12). Worked bone, volcanic glass, hooks and sinkers cluster in a sub-group again supporting the association of worked bone and volcanic glass. The bonito hook activity set seems suggested to the right of 0 with bonito hooks and chisels clustering although worked shell and drills are isolated.

Figure 4b extends the view to 2-dimensions. Here the two groups appear somewhat clearer although hook blanks are still somewhat separated from the "other" hook group and worked shell and drills from the bonito hook group. Finally- Figure 4c places the data into 3-dimensions, and here the groups become much clearer. (Picks do not belong to the "other" hook group as it may appear, for they are much further forward on the "z" plane).

SUMMARY

Six factor analysis runs, four principal component analyses, one complete-link cluster analysis and one smallest space analysis in 1-, 2-, and 3-dimensions indicate two basic groups of functional artifact types cross-cut assemblages in the Hawaiian archaeological record with slight variations depending on missing data options. These groups are postulated to reflect activity sets concerned with the manufacture of shell-material, bonito hooks and bone-material "other" hooks. Shell is suggested to have been initially cut by chisels and basalt flakes and later with drills while bone is suggested to have been initially cut with volcanic glass and later worked with abraders (stone and echinoid) and drills. Octopus lures and sinkers seem to be correlated with either activity set depending on the option matrix used. Awls' presence is unexplained as their function is unknown.

In addition to these postulated activity sets, I would like to speculate on the presence of two more. Graters/scrapers constantly appear separate as a single group (ignoring ulumaikastones, poi pounders, and tattoo needles). Graters/scrapers are associated with the removal of skins from root crops (cf. Cordy, 1973), suggesting this item reflects the presence of a food preparation activity. Also adzes often appear separately as a group or with other groups in below moderate values. Adzes are a woodworking tool, and I suggest they indicate the presence of woodworking activities.

Two final notes. One, only artifacts are used in this analysis - midden and architectural features are ignored. I previously have reconstructed activity set models from the ethno-history using artifacts, midden and architectural features (Cordy, 1972, 1973). Of these activity sets, only three were predicted basically on non-perishable artifact remains; these being fishing-gear manufacturing, food preparation, and woodworking. It is rather interesting only these activity remains seem indicated in the present analysis and that the fishing-gear manufacturing set is sub-divided. Two, one may ask what use are analyses such as this. They can, first of all, indicate objectively which artifacts were used together in activity kits. These inferences are stronger than assumptions of activity kits subjectively based on artifact lists from single sites (cf. Hodson, *et al.*, 1966). Also, delineation of activity kits allows for comparisons between assemblages, revealing similarities and differences in assemblage activities, which can have a great influence on data interpretation (cf. Binford and Binford, 1966). Figure 5 illustrates a comparison between three assemblages from this paper's data. In addition, analyses such as this one can possibly reveal heretofore unknown functions and relations between artifacts in the archaeological record. Finally, activity sets formulated in analyses such as these can be used by archaeologists to identify activity areas within sites they are excavating.

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All artifacts listed in Figures 1-5 are coded as follows:

1 - Other Fish-hook	11 - Volcanic Glass
2 - Other Fish-hook Blanks	12 - Basalt Flakes
3 - Bonito Fish-hook	13 - Adze
4 - Abrader	14 - Drills
5 - Echinoid Abrader	15 - Chisels
6 - Octopus Lure	16 - Graters
7 - Sinker	17 - Poi Pounder
8 - Awl	18 - Ulumaika Stone
9 - Worked Bone	19 - Picks
10 - Worked Shell	20 - Tattoo Needle

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Fig. 1a--Factor Analysis
"No Options": Dominant Artifacts

Factor	65-case	44-case	30-case
1	(49.9%)	(55.8%)	(50.8%)
	.54--3	.51--3	.54--3
	.54--15	.51--15	.54--15
	-------	-------	-------
	.39--10	.39--10	.35--10
	.36--14	.39--14	.34--14
2	(19.3%)	(20.3%)	(20.8%)
	.70--17	.57--13	.68--12
	.57--12	.56--12	.58--13
	-------	-------	
	.25--14	.33--16	
3	(12.2%)	(11.6%)	(11.3%)
	.62--13	.74--19	.86--19
	.57--16	-------	
		.41--16	
4	(7.0%)	(6.5%)	6.7%)
	.89--7	.86--7	.89--7
5	(6.2%)	(5.8%)	(5.6%)
	.82--19	.36--11	.81--16
	-------	.34--8	-------
	.26--5	.34--6	.37--14
		.33--2	
6	(5.4%)	.33--9	(4.7%)
	.36--8	.33--4	.35--11
	.35--11	.31--1	.33--6
	.34--6	.30--5	.33--8
	.33--2		.32--4
	.33--4		.32--2
	.33--1		.31--9
	.31--9		.30--1
	.29--5		.28--5

Fig. 1b--Factor Analysis
"Option 2": Dominant Artifacts

Factor	65-cases	44-cases	30-cases
1	(46.3%)	(44.9%)	(42.9%)
	.51--7	.54--18	.54--18
	.45--3	.51--16	.50--16
	.44--12	.44--17	.44--17
	.40--6	-------	-------
	------	.25--8	.24--8
	.30--8		
2	(21.0%)	(21.6%)	(22.2%)
	.56--9	.50--7	.50--7
	.56--11	.44--12	.44--3
	-------	.44--3	.43--12
	.33--20	.39--6	.39--6
	.26--8	------	------
		.31--8	.31--8
3	(14.9%)	(15.7%)	(16.0%)
	.66--10	.63--10	.64--10
	.55--15	.53--15	.48--15
	-------	-------	-------
	.30--20	.30--20	.33--14
			.31--20
4	(9.7%)	(9.7%)	(10.6%)
	.57--16	.57--11	.56--11
	.54--18	.52--9	.53--9
	.40--17	-------	-------
	-------	.37--20	.36--20
	.30--13		
	.26--8		
5	(8.2%)	(8.0%)	(8.3%)
	.40--19	.41--19	.41--19
	.38--1	.38--1	.38--1
	.38--4	.37--4	.37--4
	.37--14	.36--2	.36--5
	.37--5	.36--5	.36--2
	.36--2	.35--14	.33--14

Fig. 2a--Principal Components Analysis No Options: Dominant Artifacts

Principal Component 1	PC2	PC3	PC4	PC5	PC6
65-cases:					
(51.6%)	(20.0%)	(12.6%)	(7.2%)	(6.4%)	(5.6%)
.96--1	1.02--3	1.02--17	.89--13	.97--19	1.03--7
.92--9	1.02--15	.91--12	.84--16	-------	-------
.92--4	-------	-------	-------	.40--5	.34--18
.91--1	.82--10	.53--18	.52--18	.34--9	.34--20
.90--5	.77--14	.53--20	.52--20	.31--18	.30--16
.89--8	.65--18		.42--14	.31--20	
.89--2	.65--20		.39--12		
.85--6					
.80--18					
.80--20					

.41--10					
30-cases:					
(57.7%)	(23.7%)	(12.9%)	(7.6%)	(6.4%)	(5.4%)
.99--11	1.05--3	1.08--12	1.07--19	1.05--16	1.07--7
.95--6	1.05--15	.99--13	--------	-------	------
.94--4	-------	-------	.38--5	.56--14	.32--17
.92--8	.86--14	.52--17	.33--17	-------	.32--18
.91--1	.85--10	.52--18	.33--20	.36--17	.32--20
.91--5	-------	.52--20	.32--9	.36--18	.30--1
.90--2	.64--17	-------		.36--20	
-------	.64--18	.30--8			
.77--17	.64--20				
.77--18					
.77--20					

.37--10					

Fig. 2b--Principal Components Analysis Option 2: Dominant Artifacts

Principal Component 1	PC2	PC3	PC4	PC5
65-cases:				
(45.4%)	(20.6%)	(14.6%)	(9.5%)	(8.0%)
.93--1	.98--7	1.03--9	.98--18	.99--10
.91--2	.93--12	.95--11	.91--16	.78--15
.91--4	.90--3	-------	-------	-------
.90--5	.84--6	.74--20	.69--17	.42--20
.89--14	-------	-------	-------	.39--3
.87--19	.71--8	.46--5	.55--8	.37--14
-------	-------	.40--10	.48--13	
.51--20	.47--17	.39--4		
.49--12	.37--13	.38--8		
.46--6	.30--1	.32--18		
.44--13		.32--2		
.40--9				
30-cases:				
(43.9%)	(22.6%)	(16.4%)	(10.8%)	(8.4%)
.94--1	.99--7	1.03--18	1.03--9	1.01--10
.93--2	.94--12	.89--17	.96--11	.71--15
.93--4	.91--3	.86--16	-------	-------
.91--5	.84--6	--------	.75--20	.50--14
.88--19	-------	.54--8	-------	.48--20
.87--14	.72--8	.52--3	.45--5	.38--3
-------	-------	.49--10	.35--4	
.51--20	.48--17	.46--9	.32--8	
.51--12	.41--13	.43--13	.32--10	
.44--6				
.41--13				
.39--9				

Figure 3a
Johnson's Complete-Link Cluster Analysis

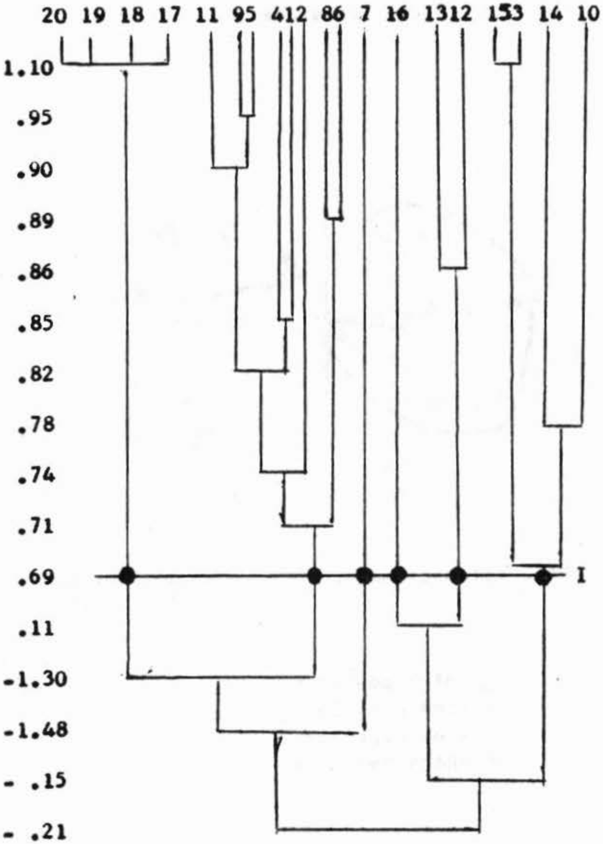


Figure 3b

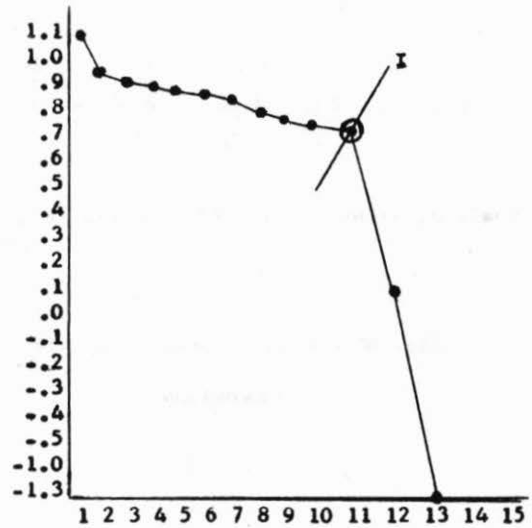
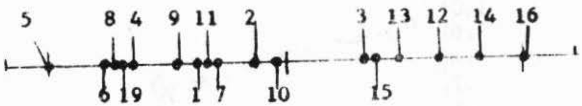


Fig. 4a--Smallest Space Analysis

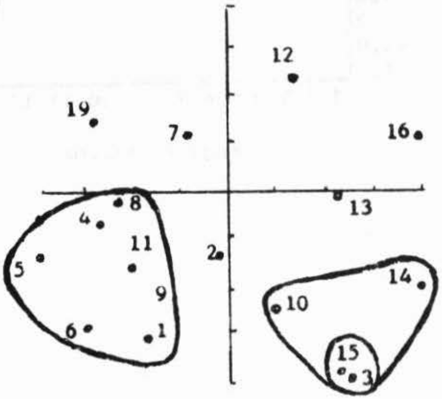
1-dimension



Coef. of alienation=.42272 Kruskal's stress=
.34396

Fig. 4b--Smallest Space Analysis

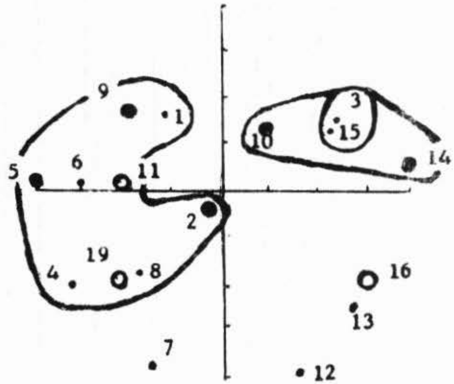
2-dimensions



Coef. alienation=.24159 Kruskal's stress=
.20250

Fig. 4c--Smallest Space Analysis

3-dimensions



Coef. alienation=.16109 Kruskal's stress=
.13872

- O -High positive
- ● -Low positive
- • -Low negative
- ● -High negative

Fig. 5--Assemblage Comparisons: Cumulative Graphs

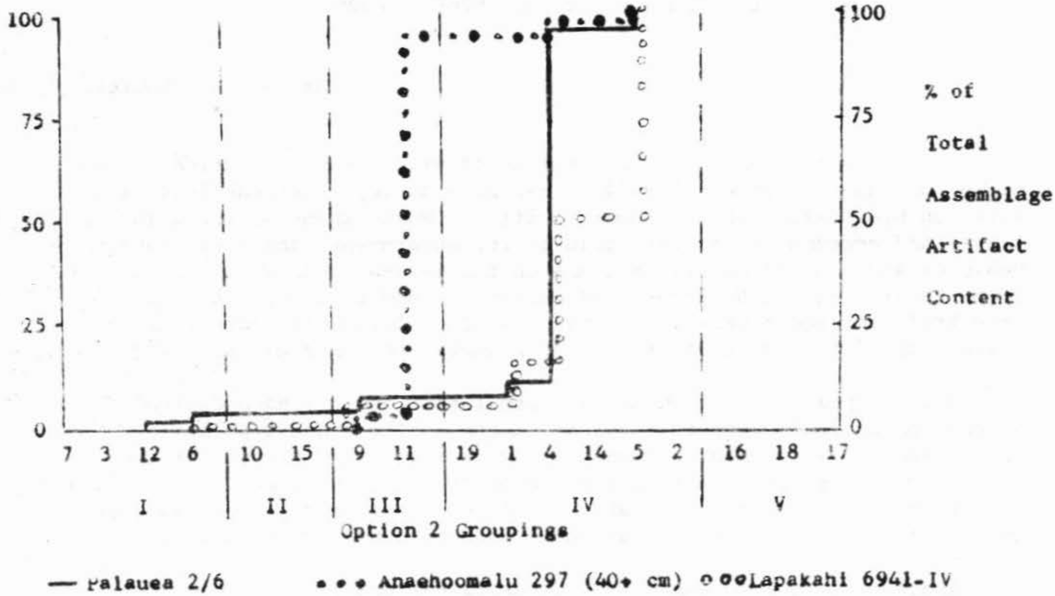


Fig. 5 (contd)--Bar Graphs

Groupings	Palauea 2/6	Anaehoomalu 297	Lapakahi 6941-IV
I--Bonito hook set	3		2
II--Shell cutting			
III--Bone cutting	4.5	92	4
IV--Other hook set	88.5	8	88
V--Possible food & leisure			
Total % of assemblage	96	100	94