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Settlement structures in Ancient Greece:

model-based approaches to analysis

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1. Introduction

> 'Without a geographical basis the people, the makers of history, seem to be walking on air', Michelet (1869) quoted by Cartledge (1979:3).

In this paper, we explore the potential of some methods of modern geography in relation to some problems of analysis in ancient history. We also draw on anthropology and archaeology and the approach is essentially multi-disciplinary. The subject of study is Greece in the period 900-700BC. We take as given the sites of any kind of settlement in this period, known from archaeological evidence. The issue is then: can the geographical analysis of settlement structure throw any light on issues of concern to historians? In particular, we are interested in the concept of the 'polis' - usually translated as 'city state' - small regions each containing a number of settlements and usually including a 'capital' and other questions of boundary drawing and regionalisation.

The key idea in the geographical analysis is that of spatial interaction: that there would have been some kind of interaction between settlements and that this would be greater between those settlements within a *polis* or other political or administrative region. By an extension of this analysis, it is also possible to predict, with virtually no input except the spatial relationship of the sites to each other, the relative importance (sizes?) of the different settlements.

We present the argument as follows. In the next section, we examine the context and the problem in more detail. Then, in Section 3, we review past research which has been based on interaction concepts - mainly in archaeology. In Section 4, we present the basis of the geographical analysis and present some illustrative results. We explore the light shed on the historical problem in Section 5, presenting a wider selection of results in the process. We offer some concluding comments in Section 6.

Note on the spelling of Greek names:

It is impossible to be entirely consistent in the transliteration of Greek words. Except for very common names the nearest English equivalent has been prefered, thus Thukydides, not Thucydides, and Athens not Athenai.

2. The Context and the Problem

When Mykenaean civilisation collapsed around 1100 BC, Ancient Greece entered a Dark Age lasting approximately 400 years. Towards the end of that period the primary institution by which Greek life was organised, the *polis*, developed. Translated 'city-state', the classical *polis* comprised: (1) a group of people sharing a common but exclusive identity; (2) their possessions (land, buildings etc.); (3) usually, but not necessarily, a 'capital' settlement. The *polis* embodies a union, ideological and physical, of people living in dispersed settlements within a territory. The question posed is: can analysis of the settlement pattern shed light upon this union?

There are two major subsidiary problems. First, *polis* does not have an agreed definition. Since there is no agreed 'physical' requirement we cannot identify a *polis* from archaeological evidence (an analogy would be the recently-abandoned 'cathedral-city' criterionin England). Common practice is recourse to the criterionof political autonomy, so that a group's *polis*-status depends upon its autonomy or subjection to another group. Apart from the fact that evidence of this kind is frequently lacking, it has the absurd result that x group periodically dominated by an aggressive neighbour yoyos between *polis* and non-*polis* status. Secondly, there is the nature of the evidence. During the period under consideration (900-700 BC) we are heavily dependent upon archaeological evidence. Such is by definition incomplete, constrained by the overarching parameters of survival and discovery. No less important, archaeological evidence needs to be interpreted; that is, it needs to be given meaning. Its oft-quoted truthfulness is due at least in part "to the fact that it cannot speak" (Grierson, 1959: 129). The major limitations are: (1) A Korinthian pot found at Athens does not *prove* that a Korinthian brought it to Athens, nor even that an Athenian went to Korinth. In sufficient quantities it may *suggest* a direct link; (2) rarely do we have such quantities; (3) the provenance (origin place) of a find is rarely accurately identifiable; (4) even the best known styles are not entirely secure in terms of chronology (it would appear that nobody died in Attika in the third century BC[1])nor of their 'real' homes (Coldstream, 1983: 25). We hope that some of these problems can be overcome indirectly by making hypotheses about spatial interaction and exploring their consequences. In passing, we can shed light on other aspects of regionalisation and begin an investigation as to whether the settlement structure of this period is a 'blueprint' for later periods.

3. Review of past work

Site interaction has been approached from two main directions, broadly distinguishable as: that practiced by Classicists (under 'Classics' subsuming Classicists proper, Classical Archaeologists, and Ancient Historians); that practiced by Everybody Else. Classicists "traditional trance-like contemplation of truth and beauty" (Snodgrass, 1984: 230) is probably the result of a long and complex relationship between Ancient Greece and those who have long considered themselves its cultural heirs. "Customarily either allergic or totally deaf to ideal types" (Finley, 1983: 12), Classicists are not apt to embrace mathematics with enthusiasm, even if the symbols are familiar to them. This is not to say that Classicists do not employ mathematics at all in their work; it is just a good deal less explicit and less rigorous. This is not entirely reprehensible(2).

The Classicists' approach is essentially 'cultural' in a traditional sense(3). Evidence collected, analysed and presented with the Classicist's eye for detail and fondness for completeness, such as Beazley's cataloging of 16,000 Attic vases, Mommsen's tomes on Roman inscriptions, or Farnell's hefty volumes on Greek cults, can provide an exemplary model to follow, even if interests of the present determine that questions posed are more concerned with action than aesthetics. And while the analysis offered here is not of this kind, we wish to stress that it aims to complement, not 'replace', the traditional kind of analysis.

Coldstream (1968, 1977), Desborough, (1952, 1964, 1972) and Snodgrass (1971) have produced valuable surveys of the material record during the period under consideration(4). Their contribution to interaction studies may be summarised as the attempt to identify, isolate, and relate regional styles to each other, with the possibility of making inferences about interaction on the basis of their findings. Scientific analysis of clays, marbles and metals has at least begun to follow a similar (laudatory) path, though we are still awaiting the first wide-ranging survey of the Greek world[5].

The main problem to be faced lies in the relationship of the find to the people who created, used and left it. It is the interpretations, not the evidence itself, which create 'paradoxes'[6]. This is the germ of the 'New' archaeology (new in the sixties that is), and fundamentally defines the objectives of its practitioners. Insecure in this infant subdiscipline, but very broadminded and extremely hospitable[7], the new archaeologists adopted many children from neighbouring disciplines[8]. Amongst the deluge of imported ideas was the idea of a 'model' and this included a concern with spatial interaction. In such studies,[9] patterning and interaction can be broken down into three broad categories: (1) gravity models, the simple version of which being $I_{ij} = \frac{P_i P_j}{D_{ij}}$ where I_{ij} is interaction between settlements i and j, P_i is population of i, and D_{ij} is the distance between the settlements. Tobler and Wineburg (1971) inverted the equation to attempt the prediction of settlement location; (2) central place theory which has been applied (in pure or adapted form) to archaeological problems on a number of occasions - for example by Renfrew and Wagstaff (1982) on the Greek island of Melos. The most common related analyses are nearest-neighbour analysis and Thiessen polygon construction (eg. Bintliff, 1984); (3) dominance models, of which the simple version is $I = f(C) - k.d$ where I is the influence of a centre at a point, C is the size of the centre, d is the distance between x and the centre, and k is a constant (Renfrew and Level, 1979). Such spatial analyses have provided only limited insight into the problems tackled however, and the calls which have been made (to some of which the model presented here is addressed) are a considered response to their perceived shortcomings[10]. In modern geography, the kind of spatial interaction model mentioned above has been replaced by something more refined. One of the purposes of this paper is to see if there are any gains to be achieved from applying such models in historical or archaeological contexts.

4. The Geographical Analysis of Interaction and Settlement Structure

It is important to begin by saying that the notion of 'interaction' being used here is that of a rather broad indicator. The flows may be economic, migration or the exercise of political control and we use a single rudimentary index to represent all of these. Similarly, what we might sometimes be tempted to call settlement 'size' (which it would be in a contemporary context) is also a broad index - of 'importance'[11]. We can perhaps take some comfort from Thukydides' observation in the fifth century BC that size may not in any case be an accurate indicator of importance:

> "Suppose, for example, that the city of Sparta were to become deserted and that only the temples and foundations of buildings remained, I think that future generations would, as time passed, find it very difficult to believe that the place had really been as powerful as it is represented to be. Yet the Spartans occupy two-fifths of the Peloponnese and stand at the head not only of the whole Peloponnese itself, but also of numerous allies beyond its frontiers ... If, on the other hand, the same thing were to happen to Athens, one would conjecture from what met the eye that the city had been twice as powerful as in fact it is"[12].

We work with 109 sites as shown on the map at Figure 1[13]. Their known (or hypothesised) names are given on Table 1. We have calculated the Euclidean distances between each pair of sites; and then we have modified some of these distances to allow for the difficulties of terrain - crossing mountain ranges and so on. Otherwise, we have made no other prior assumptions at this stage. We do not distinguish in any of the analyses settlements which are currently thought to be of different magnitudes of size, or of different functions; though we do later make some deductions about possible size distributions as a product of the analysis.

Each site, i (or j) has two indices associated G_i and W_i (or G_j and W_j). The first of these is intended to be an index of population; the second, an index of economic or political importance and activity. Initially, as noted in the previous paragraph, we assume equal sizes of the G_i-indices and that the interaction takes the simple form

$$S_{ij} = KG_iG_je^{-\beta c_{ij}} \qquad (1)$$

for some constant K. $e^{-\beta c_{ij}}$ is a convenient decreasing function of distance, c_{ij}, though alternatives could be used[14]. β is a parameter which determines how rapidly the level of interaction S_{ij} declines with distance: the larger β, the more rapid is this decline.

These calculations leave us at about the same level as the authors mentioned in Section 3. We now add four new methods of analysis, three of which have a longish (twenty-year) history in geography, but the last of which is relatively recent. These are concerned with: (i) the calculation of measures of accessibility (cf. Hansen, 1959); (ii) the development of alternative interaction models (cf. Lakshmanan and Hansen, 1965; Wilson, 1971); the analysis of interaction patterns (cf. Nystuen and Dacey, 1961, as generalised by Wilson in Wilson and Kirkby, 1975); the prediction of settlement size - or, in this context, 'importance' (Harris and Wilson, 1978, Wilson, 1981).

There is also a major feedback because once settlement importance (W_j) has been estimated, it can be used as an alternative basis for the first three approaches. We outline each kind of exploration in turn.

Accessibility

A measure of access to population from i is (cf. Hansen, 1959; and for a broader review, Black and Conroy, 1977):

$$X_i^G = \sum_j G_j e^{-\beta c_{ij}} \tag{2}$$

Two elements are traded off in the summation term: size and a decreasing function of distance. Thus a small settlement nearby and a large settlement some way away may contribute the same amount to this index of accessibility.

A similar measure of access to facilities can be measured in relation to our index of importance, W_j:

$$X_i^W = \sum_j W_j e^{-\beta c_{ij}} \tag{3}$$

We also have a third accessibility index using the feedback-W_j's, W_j^F (which are explained below):

$$X_i^F = \sum_j W_j^F e^{-\beta c_{ij}} \tag{4}$$

Calculations of all three accessibility measures, computed for $\beta = 0.9$ and for $\beta = 0.1$ are presented in Table 2. On the whole, it is the relative (between-zones) values of these indices which are useful, but the indices are much higher, of course, for the lower β value. However, there is more relative difference between sites for the higher β value. If the values are compared with the locations of the sites on Figure 1, then it can be seen that the accessibility values make intuitive sense, especially if comparisons are restricted to zones in the same 'region' - which begs a question, of which more later.

A clearer understanding of all the elements of Table 2 will be obtained when we have described the procedure for calculating $\{W_j\}$ and $\{W_j^F\}$ below.

Interaction models

The model given by equation (1), the old 'gravity' model, is for most purposes dimensionally incorrect. If G_i is doubled and G_j is doubled, then S_{ij} is multiplied by four. Usually, we would prefer it to be doubled. This can be achieved by using, say, the so-called singly-constrained model (cf. Wilson, 1971):

$$S_{ij} = A_i G_i G_j e^{-\beta c_{ij}} \tag{5}$$

where

$$A_i = 1/\sum_j G_j e^{-\beta c_{ij}} \tag{6}$$

to ensure that

$$\sum_j S_{ij} = G_i \tag{7}$$

(G_i in equation (7) can be replaced, more plausibly, by KG_i, without affecting the argument). We then get doubling of S_{ij} when G_i and G_j are doubled. However, a more interesting model is

$$S_{ij} = A_i G_i W_j^{\alpha} e^{-\beta c_{ij}} \tag{8}$$

where

$$A_i = 1/\sum_j W_j^{\alpha} e^{-\beta c_{ij}} \tag{9}$$

which computes interaction in relation to the 'population' at i and the 'importance' of j - the latter being raised to a power, α, as there is no reason why the relationship should be linear.

Once we have used the procedure (yet to be described!) to find the W_j which is used above, we can then ease the assumption that all the G_i's are equal, and set $G_i = W_i$ and then use the settlement-size routine to calculate new W_j's which we call W_j^F, the feedback W_j's. There is then a corresponding fourth possible form of interaction model:

$$S_{ij} = A_i W_i (W_j^F)^{\alpha} e^{-\beta c_{ij}} \tag{10}$$

with

$$A_i = 1/\sum_j (W_j^F)^{\alpha} e^{-\beta c_{ij}} \tag{11}$$

In the results presented below, we use three of the four models:

I - model 1 : equation (1)
I - model 2 : equations (8) and (9)
I - model 3 : equations (10) and (11)

We retain the equation (1) model to provide a base for comparing our work to others who have used such a simple model. The model given by equations (6) and (7) is rather artificial and not very interesting. The other two models are interesting because of their links with the settlement size prediction method to be described shortly. First, however, as a preliminary, we present a method for analysing and presenting graphically any interaction matrix produced by one of the above models.

Interaction-pattern analysis

Suppose we have an interaction matrix $\{S_{ij}\}$ from one of the methods above. In this example, this is a 109x109 array and it is useful to have a method for presenting the key features. We proceed as follows. Calculate

$$D_j = \sum_i S_{ij} \tag{12}$$

This is the total interaction inflow attracted to j and is taken as a measure of the importance of j. For each zone i, we can then calculate J_i, the j-value for which S_{ij} is a maximum. i is said to be a *terminal* if $D_i > D_{J_i}$; that is, if J_i is a lower order node than i itself. We then calculate an array $\{N_{ij}\}$ whose elements are zero except for those which are set to 1 if: (i) $j = J_i$; (ii) i is not a terminal; (iii) $D_i < D_j$. When $N_{ij} = 1$, we plot a link connecting i to j. This is the original Nystuen and Dacey (1961) procedure and it generates one link per zone. Because of the way terminals are defined, it displays any hierarchical structure in the interaction matrix. Examples are shown in Figures 2 and 3 for interaction matrices derived using the simple model 1, with $\beta = 0.9$ and $\beta = 0.1$ respectively.

The obvious possible snag with this procedure is that by selecting one link per origin zone, there may be other interactions where the flow is very close to the maximum and where a better overall picture would be obtained if links were plotted; or we may wish to overide the condition that i must not be a terminal and add a link in that case if D_j is greater than some constant. We handle the first case by plotting a link ($N_{ij} = 1$) if $T_{ij} \geqslant$ constant x T_{iJ_i}. Plots are shown in Figures 4 and 5 which are repeats of Figures 2 and 3 but with this factor set to 0.5. We show plots for interaction matrices from models 2 and 3 when we have discussed further below how these models are derived.

Settlement-size pattern prediction

We now show how the arrays $\{W_j\}$, and then $\{W_j^F\}$ are derived. The method involves adding an hypothesis about W_j relative to D_j. Assume that W_j is measured in the same units as S_{ij}; calculate $\{S_{ij}\}$ from model 2, equations (8) and (9), using a set of guessed $\{W_j\}$ - probably taking $W_j = G_j$ as starting values. Then, if $D_j > W_j$, the calculated 'importance' of j exceeds the original estimate, and the hypothesis is that W_j should be increased; and vice versa. At equilibrium, we require

$$D_j = W_j \tag{13}$$

We can substitute for D_j from (12):

$$\sum_i S_{ij} = W_j \tag{14}$$

and then for S_{ij} from (8) and (9):

$$\sum_i \frac{G_i W_j^{\alpha} e^{-\beta c_{ij}}}{\sum_j W_j^{\alpha} e^{-\beta c_{ij}}} = W_j \tag{15}$$

These are nonlinear simultaneous equations in $\{W_j\}$ and, for given values of α and β, can be solved, to give a prediction of $\{W_j\}$, which is the spatial pattern of settlement sizes.

This model has been widely applied and investigated in a variety of situations in geography - cf. Wilson and Clarke (1979), Clarke and Wilson (1983). In the present case, when we start with an assumption of equal G_i's ('populations'), it provides a way of estimating a likely pattern of settlement importance. It is necessary to run the model for a variety of α and β values to see if it generates patterns which contain implicit regionalisations of historical significance. The results can be conveniently displayed using the extended Nystuen and Dacey method of interaction pattern analysis. Such plots are interesting in themselves, because model 2 is likely to be better than model 1: it is the equations

(8) and (9) model with $\{W_j\}$ being obtained from the above procedure. But the terminals in these plots are also likely to be the settlements which are given high values of W_j, and this information can be reinforced if such nodes are circled - so the N-D plot becomes a presentation also of the $\{W_j\}$ pattern, at least in broad terms. Figures 6 and 7 parallel Figures 2 and 3 and show such plots for $\beta = 0.9$ and $\beta = 0.1$ for the unextended N-D case; and Figures 8 and 9 are the plots with the T_{ij} factor set at 0.5. In each of these cases, we took $\alpha = 1.01$. Again, the $\beta = 0.1$ case generates a much more hierarchical structure than $\beta = 0.9$; but we leave issues of interpretation to the next section.

The final step in the argument arises as follows. We were forced to obtain models 1 and 2 with all the G_i's set equal. Now that we have a W_j for each settlement, we can take

$$G_i = W_i$$

and rerun this procedure to calculate new W_j's, which we call $\{W_j^F\}$ to indicate that they have arisen from this feedback. We can then present the plots for model 3, and this is done in Figures 10 - 13, which parallel Figures 6 - 9. As would be expected, the settlement pattern is made more hierarchical for these α and β values.

Summary of analyses which can be carried out

The key to understanding the results as a prelude to interpreting them in more depth lies in the different models 1, 2 and 3 which are generated using $\{G_j\}$, $\{W_j\}$ and $\{W_j^F\}$ as measures of destination-zone 'importance' respectively. These generate the three accessibility measures shown in Table 2 and the three interaction pattern (IP) analyses shown as Figures 2-5, 6-9 and 10-13 respectively. The second two sets of figures show the two settlement pattern (SP) analyses which can be obtained - using $\{W_j\}$ and $\{W_j^F\}$ respectively. In this last case, it may be better to present a full table of W_j- and W_j^F-values, and this is done for the examples we have been using in Table 3.

The main remaining task is to run the models for a variety of α and β values and to attempt to select both model or parameter values which appear to generate analyses which have historical significance. We pursue this in the next section.

5. Preliminary analyses

In this section, we present further results and begin to indicate how these can be interpreted in relation to a variety of topics of interest. First, we outline the hypothesis according to which the analyses are interpreted. We consider which parameter values are appropriate and the ways in which results may be examined. We then consider how the interaction patterns so derived can be used to shed light on (i) the formation of groups; (ii) the emergence and development of centres; (iii) intra- and inter-regional interaction. We have, of course, an hypothesis in mind, a mental framework, within which we interpret the analyses results, to identify 'interesting' or even 'valid' results. It is important to outline this, and will in addition provide the background for those less familiar with early Greek history.

Between circa 900 and 700 BC Greek society witnessed the emergence of the *polis*. Factors involved probably included technological and agricultural innovations, population rise, the emergence of markets, festivals, general assemblies, and human agency.* At the start of this development society was egalitarian, settlements were small and were aggregations of households. The only social unit, as delineated by Smith's five minimally necessary articulations (Smith 1977: 42), was the *oikos*, or household, which was (by necessity) self-sufficient in all *necessary* requirements. Exchange of goods between *oikoi* took place on an informal, sporadic, and unpredictable basis, and was probably not immediate. More likely something was offered to a neighbour or neighbours as a gift, with no stipulated date or value of return, but with an implicit understanding that the gift would be reciprovated at some time in the future (perhaps as much as 30 years later). 'Prestige

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* "The man who first constructed such an association (the *polis*) was ... the greatest of benefactors" (Aristotle *Pol* 1253a 15.

goods', probably acquired through raiding, may have entered the system to be exchanged within it.

Communications were, on the whole, poor. The dominant mode of transport was Shank's Pony, rarely a real one, and there was perhaps some communication by sea.(15) This constraint affected not only personal travel, but also how much 'produce' or 'goods' could be transported from i to j. Most people depended upon the land for their livelihood, and there were few 'specialised' trades.(16) Infrequently households would meet, eg. for 'rites of passage' type occasions (initiation rites, spouse-finding, marriages, etc.) or for group action in times of need (external attack, drought, etc.). In view of the communications situation, such meetings were likely to take place at a location most easily accessible to the participants. Further, in view of the increased likelihood of conflict between participants, such a location was likely to be protected by some higher authority, namely religion. Thus the location is likely to be, or to be made, a site of religious significance.

A place where meetings were held became an attractive locus in a region defined by the distance people could or would travel to participate. Competition within a region so defined probably began, but ceased fairly quickly once one locus achieved superior importance. Such a locus was determined primarily by its centrality. Having established a lead, it occluded its rivals, which assumed a lower order importance, and precluded any rival centre capable of competing effectively from emerging within the region. Established attractiveness draws more participants in a self-perpetuating cycle. This process is extremely resilient and resistant to change (Wanmali 1981:77-87). Rising standards of living, more frequent and more regular meetings, probably 'festivals' (with consequent increase in exchange of goods and information, and reinforcement of a common identity consciousness) and human agency in developing such meetings and meeting places created foci. There would be an impulse for people to move their houses toward the meeting place, whilst retaining their original land, exchanging 'commuting time' to the fields for the benefits accruing from a larger aggregation of people (thus commuting in the opposite direction to modern practice; this is in fact the common practice of Greeks ancient and modern): benefits economic, political, social, cultural and, fundamentally, 'human to the Greeks' way of thinking. "Man is by nature an animal intended to live in a *polis*" said Aristotle (*Pol.*1253a 9, commonly mistranslated Man is a political animal).

A suggestive model of communication spheres is given in figure 14. (developed *polis*).

The formation of groups

It is first necessary to find the parameter limits beyond which analyses are invalid in the particular case study, that is, the known or hypothetical levels of interaction and centralisation. We need therefore to establish the 'average' level of centralisation and the 'usual' level of interaction within and between *poleis*. Composed of hundreds of independent small states, high centralising values are generally inappropriate in the Greek case. Communication levels are difficult to ascertain, but during the Geometric period (and seeking 'usual' interaction levels) high values are again generally inappropriate. If, however a large *polis* such as Athens, or unusual interaction such as that between major *poleis* and 'borderlands', is the object of investigation, higher values are appropriate, indeed required. Having established the various parameter ranges for each type of interaction, we can begin to explore spatial relationships under various circumstances. Systematic rerunning, producing a block of results, can be examined in two main ways (i) focus on individual 'interesting' runs (eg. #in the diagram below); (ii) analysis of the complete block for overall trends and consistency. Each 'run' employs all models explained above, and can be analysed similarly by focus upon (a) individual model 'interesting' results; (b) the complete 'run' incorporating all models. Here we shall present a selection of interesting individual analyses, reserving proper discussion of mass data analysis, as required by methods (ii) and (b) for separate treatment in a forthcoming paper.

		β				
		0.9	0.7	0.5	0.3	0.1
	1.1	x	x	#	x	x
	1.25	x	x	x	#	x
α	1.5	x	#	x	x	x
	1.75	x	x	#	x	#
	2.0	x	x	x	x	x

= possible 'Interesting' runs among a selection of (α, β) parameter values.

In the early stages of the hypothesised development when sites were small and interaction slight, we should expect groups to be relatively small also: the importance of sites to be determined primarily on geoghraphic grounds; and differentiation in 'importance' to be slight. Figure 15 has the topography roughly suggested, and although six sites had been weighted to reflect major topographic barriers(17) the general accuracy for 103 sites achieved without modification is considered satisfactory. Due to (i) the size of the survey area; (ii) the evidence differential between regions (some have seen more survey/excavation than others) and (iii) the variation in *polis* territorial areas (18) a group may represent (a) a district (pre-*tritty*?) of a large *polis*, (b) a group of sites (perhaps of uncertain status, one of which may be a 'capital') which may comprise a *polis*, (c) a group of sites including more than one *polis*. Looking to figure 10, an example of (a) is the group including Menidi (ancient Achamai) one of the largest *demes* (borough) of Attika, and Kephissia, one of the original twelve towns to unite in the creation of the Athenian *polis* (Strabo, 9.1.20). An example of (b) is the group comprised of nos. 37, 38 and 39 which may be Hysiai, Erythrai and Skolos respectively(19). It is believed that the model can assist valuably in problems of site identification, but limitation of space prevents its proper treatment here. An example of (c), is the group including Kopai (no.5) and Akraiphnion (no.7), both independent states at some time(20). Buck argued((1979:100), after Wilamowitz) for a coalition between the two, but the relationship between them and the other sites in the area is at best ambiguous.

The emergence and development of centres

As certain sites achieve superior importance foci emerge (cf. fig.16). We hypothesised that such foci were likely to be sites of religious significance: three sites of predicted high import, the Argive Heraion (ranked 2) Isthmia (ranked 7) and Korinth (ranked 12) are thought to evince the three earliest examples of stone temple construction within the survey area[(21)]. Brauron (ranked 6) was an important sanctuary of Artemis - whose cult was brought to Athens by Peisistratos - and Hyria (ranked 4), Koroneia (ranked 9) and Medeon (ranked 10) are all very close to known important sactuaries of Artemis, Athena and Poseidon respectively. We also note that major cities in Greek history, Athens (ranked 1) and Thebes (ranked 5) are predicted to have established importance fairly early on, that is, at low levels of interaction and centralisation. It is of interest that the remaining 'important' site, Ay. Ionnis (ranked 3) has not yet been excavated, but possesses an enormous fortress, larger than "Tiryns of the huge walls" (Homer *Iliad* 2.559. cf. Hope Simpson 1965:118. Leekly & Efstratiou 1980: 17-18).

The degree of hierarchy within and between *poleis* was usually relatively small, not only during the period under consideration but also in the succeeding, the Archaic, period, and to a lesser degree, in the next, the Classical, also. This is an important consideration governing not only the establishment of parameter ranges, but also the interpretation of analysis results, especially in connection with the development (beyond the geometric period) of centres. The smallness may be illustrated by reference to the number of graves of geometric date discovered at the main settlements in the Argolid, for which there is a solid body of data:

Argos	186+ (14+)
Asine	19 (3)
Lerna	22 (3)
Mykenai	14 (1)
Nauplia	31+ (5)
Tiryns	69+ (6)

(Source: Hagg 1974: Tab.1 and 19. Figures in brackets indicate the number of child burials)

This for a period of 200 years. Allow a thirty year lifespan (this may be generous cf. Snodgrass 1980:18) and we are dealing with very small settlements. The preponderance of Argos is due in no small measure to the fact that the figure given is the total from fourteen different findspots and cemeteries in districts of modern Argos: it almost certainly represents several individual settlements.

A handful of *poleis* did achieve a position from which they could dominate Greek history, as preserved to us at least, however. Within the survey area these would include Athens, Korinth, Thebes and Argos. When parameters are set to high interactive and hierarchical levels, these centres are indicated fairly closely, as in figure 17. We note that this individual analysis does not predict exactly each of the above sites - not surprisingly, since the floruit of each was at different times and under differing conditions, whereas the model defines one set of conditions. Nevertheless, it can be seen that the 'greatness' of these cities may in some degree be due to the spatial relationship of their small, geometric period predecessors.

Intra- and inter-regional interaction

The analyses can also assist in the investigation of interaction within and between regions. Allowing for higher levels of interaction we expect to find a degree of regional definition, which should again be fairly true to the topography. First we find the parameter values which reflect fairly accurately the regional situation as known from historical sources. Problems of a regional nature, such as the analysis of pottery styles, can then be tackled. In order to facilitate comparison between this kind of approach and 'traditional' methods, and indicate how they can assist each other, all references are to one recent, concise discussion by a leading authority, Coldstream 1983, and the main regions have been indicated on figure 18.

In the Argolid, vases of our period from the same workshop have been found at Mykenai, Tiryns, Nauplia, Asine, and their probable home, Argos (*ibid*: 23). The analysis reflects the identification of a clear local character by depicting relatively heavy interaction within the region, but little with outside. Similarly, Korinthian is a clearly recognisable style, and at Krommyon, sometimes thought to be a 'bordertown' between Korinthia and the Megarid, pottery (and burial practices) were found to be wholly Korinthian (*ibid*: 22), as indicated by the analyses time after time (see figures 15, 16, 17 etc.). In Boiotia no clear regional style can be discerned (partly due to the fact that it has not received as much attention) and it seems likely that a number of different schools existed. This is suggested also by the network. Whilst Attic has a distinct overall character, Athens is, as usual, known better. Coldstream suggests that there were other areas of production, and that "future research may be able to locate some workshops ...

in country districts rather than in Athens" (*ibid*: 20). He illustrates by reference to a piece from Thorikos which is not of a known Athenian hand. The networks identified by the model would also suggest the existence of districts, but can in addition predict the 'important' sites within such, and might therefore be able to suggest probable locations for these workshops, saving the archaeologist much time, trouble and expense. (The same might also apply to Boiotia.)

Looking to a different type of evidence, a particular version of the cults of Hera, Artemis and Demeter has been recognised to have a clear geographic distribution, running in a band from Khorsia, Siphai, Kreusis, Thespiai and Plataia across to Euboia in the east (Schachter 1981: 243f): the correspondence of the analysis is striking.

Regional centres are picked out and exaggerated by models 2 and 3, and problems of inter-regional interaction may then be investigated. In Greece of the period such interaction, it should be noted, was not 'usual' but unusual and infrequent. Interaction between *poleis*, rather than regions, is better reflected in, for example, figure 17. Trade, politics and festivals were probably the main impulses for such inter-regional interaction, thus from history we would expect it to occur at (i) large and important settlements; (ii) major sanctuaries, and from a different slant (iii) borderlands between regions. These three impulses were often combined, and sometimes indistinguishable to the participants, such as the festival held at the sanctuary of Poseidon at Onchestos (see figure 19). This was governed by an *amphictyony*, or council of representatives from participating *poleis*, which form of association provided the first vehicle for a foreign policy more constructive than war, the normal Greek mode for settling differences.

The value of this model-based approach is not confined, however, to enlarging upon what is known from other types of evidence; it also has considerable potential value in drawing attention to sites at present largely neglected, as to Ay. Ionnis mentioned above. One of the sites at thus highlighted in figure 19 is Kromna, situated approximately midway between Korinth, the *polis* 'capital' and Isthmia, a major panhellenic sanctuary. This site has received but passing attention, although extensive habitational remains and a large cemetery were discovered here in 1960, and the wide sherd-scatter suggests a substantial settlement dating from at least the seventh century BC and extending into the fourth century AD (Wiseman 1976: 470. Salmon 1984: 24, 35, 156).

Borderlands are another area on which the models can shed some light. Various *poleis* at different times attempted to extend their sphere of influence or control. This took various forms, sometimes by alliance, sometimes by more personal and informal routes, such as is connoted by 'friendly relations'. An area periodically subjected to such ambitious neighbours was the Megarid, which in its artistic styles for instance seems always to be heavily influenced by either Attic or Korinthian without developing a character of its own (cf. figs. 13,11,9). Similarly, the area lying between Korinthia and the Argolid held the *polis* of Kleonai, which for most of its history seems to have been allied with Argos, and the settlement of Tenea which, on the other hand, seems to have been subordinated to Korinth for much of its history.

6. Concluding comments and evaluation

Different types of evidence may be used to investigate past societies (archaeological, anthropological, literary and so on) and whilst one type cannot confirm or refute another type (Snodgrass, 1983), in combination they can provide complementary correctives to each other's partial vision[22]. Partial vision exists not only between types but, and more importantly, within types. Literary evidence is notoriously Athenocentric; honest history books state at the outset that what follows is frequently not so much Greek history as Athenian history, due simply to the fact that the vast majority of literary evidence which has survived to us concerns or was written by Athenians. Archaeology is less narrowly constrained in terms of evidence, but there are still plenty of areas (geographic and topic) almost unknown, and it must be made to speak. The consequent difference between the two partial pictures of the same thing can be quite substantial (cf. Murray's comment in Hagg, 1983: 49).

The model starts with a number of sites of assumed equal 'population', and 'develops' them initially on geographic grounds, thereafter incorporating a higher dimension approximating the 'pull' of proportionately more important sites. It is not constrained by theoretical geometries or hierarchies, and under varying conditions direction of flow can occasionally be seen to reverse. By not forcing settlements into rigid patterns and regular hierarchies, simulations are probabilistic rather than deterministic, and allow many possible 'histories' to be modelled. But whilst the details may vary, the picture remains essentially the same, and that picture is one which accords with those suggested by other approaches.

The model can work from the minimal requirement of a site's existence, yet has the facility to incorporate types and levels of evidence far beyond that available at present for Ancient Greece. It offers a framework for general interaction, a skeleton upon which specific studies, geographical or historical, can hang, at micro-, meso-, or macro-scale, and by which alternative approaches (traditional and 'new') can be complemented. By 'levelling' all sites to the same initial size and status, the model offers a coarse corrective to partiality within archaeology, and produces a picture unaffected by historical knowledge (which is always partial and often difficult to disentangle from its corollary, hindsight). This may be compared with that knowledge to frame hypotheses aiming to explain divergences from the likely paths of development. Predicted importance of a site may then be drawn upon to complement a study of literary documents, which, for example, attempt to identify a site. Similarly with archaeological evidence, the model might be employed to assist in finding the location of pottery workshops as suggested above.

Hypotheses can also be 'tested'; for instance, the deduction from historical sources that a *tyrannos* played a beneficial and important role at x site could be simulated by 'boosting' x site and comparing the results with an unmodified simulation. The findings could direct further research, which could then refine both the hypothesis and the simulation. That is, the model in harness with other approaches can be employed together to guide each other toward better understanding and interpretation, and ultimately toward better explanation.

However, modifications and interpretations require a considerable degree of thoughtful caution if the model is not to become merely self-confirming. As a rule of thumb, the more inclusive the modification, the more informative the result. The model cannot correct Athenocentric (or any other) bias if sites are individually weighted to exactly reproduce their 'importance' as deduced from other sources. Used to complement different types of evidence however, an analysis which is 'sensible' where it can be 'cross-referenced' offers a reasonable speculation for those areas also dealt with by the analysis but where such evidence is either lacking, or exists but has not been organsied or utilised to bear upon the problems posed. In other words, the model properly used can provide a kind of bibliography, guiding archaeological and archival research.

It is appropriate to conclude with a discussion of problems. First, the accuracy of the analysis is directly proportional to the accuracy of the evidence it is given to analyse, most importantly here concerning maps. Whilst the situation could be worse than we find in Greece(23) the major problems are: (i) a site must be discovered in order to be included; (ii) site identification. The problem of putting names to faces is neither easy nor unimportant, and difficulties in the field, or poring over the ancient geographers Pausanias and Strabo with map in hand, are compounded by the fact that there exists not infrequently three Greek names for one place - the Official Greek, the 'real' Greek (i.e. the one everybody, except Greek cartographic bureaucrats, knows and uses), and the ancient Greek. This creates an enormous amount of confusion, which will be solved only when everybody complies with one system of reference, preferably that of giving map coordinates. In the meantime it is necessary to keep a list of synonyms handy and, when researching, to be continually aware that one man's Tanagra might not be another man's Tanagra. In order not to conflate the two major sources of evidence (literary and archaeological), and thereby nullify much of their corrective potential, site names should be treated as labels, except where identification is secured by inscriptional or equally reliable evidence. (iii) Even when one is sure that an ancient geographer, a field archaeologist and a historian are indeed all refering to the same Tanagra, the trustworthiness of the maps available is not good, if in fact the site in question (in any of its guises) is marked, and attempts to rectify this situation need to be systematised(24). (iv) There are two kinds of temporal constraints. A. The question of development and the assumption of initial equality between sites is dependent upon the sites being contemporaneous. The accuracy of the evidence determines the margins of that contemporanity: in this case it was considered unrealistic to attempt anything less than 200 years, that being the approximate duration of the Geometric pottery style. Pottery was fixed upon because as a source of evidence it is both ubiquitous and practically indestructable, and also well known and therefore relatively easy to identify. B. The number of sites in an analysis is fixed; it is not possible to incorporate new sites during a 'run'. Consequently the model does not have a truly dynamic dimension. However, it is believed as a general assumption that later settlements are unlikely to 'overtake' earlier settlements. This assumption will be considered in a forthcoming paper.

The models may contain inadequate assumptions about human spatial behaviour which is characterised by a set of factors, more or less tangible, which can and do modify purely geographic considerations, and which are often irreducible to mathematical modelling. Above all, people operate in an environment as they perceive it, not as it is (Brookfield, 1969). The model offers the facility to experiment with reducible factors, such as 'cultural' (as assumed to be reflected in ethnic/dialect affiliations), but interpretations should always allow some space for people, thinking, feeling, *real* people, to manoeuvre.

As Hassan found using mathematical models in demographic archaeology (1981: 35), the evidence is such that quantitative estimates must be viewed within a large error margin. Estimating hunter-gatherer populations, he found that anthropological observations were better matched by the mean value of a dozen 'runs' than by any single 'run'. The probabilistic nature of the results obtained by constant rerunning of the model helps in relation to this problem.

We have concentrated on spatial groups rather than social groups. Since the problem tackled was redefined to investigate general interaction between sites, and in consequence the model developed was found to have broad applicability, the interpretation of any analysis must be restricted to the question posed in that analysis. Thus, in order to bring the analysis to bear upon the specific question of Greek *polis* formation, we need to know from other sources where to draw the line in interpretation between interaction to form groups, and interaction between already formed groups; that is, where the unification process stops. Therefore, if the model is applied to a non-historical society the results must be interpreted only within the broad margin of general interaction; and insofar as the maximum level of interaction may be assumed on *a priori* grounds, this also must be given reasonable latitude (cf. the discussion in Hagg, 1983: 49). It would perhaps be interesting to apply the model to, for example, the Dacian Iron Age culture, in order to see if any general guidelines in this matter can be established[(25)]. Where literary evidence exists, Smith's 'minimally necessary articulations' (1977: 42) can be employed to good effect to delineate, if not define, a social group.

Notes

1. Vanderpool's comment, Mussche et al 1975:17
2. See McCullagh 1984:45-47. Floud 1979, esp. 1-4. Fogel and Elton 1983. Elton 1984:11-56.
3. For an attempt to grapple with, rather than dismiss (as does Renfrew 1984:33-39) the problems involved in the concept 'culture' see Bennett et al 1983. Archaeology's concern was first clearly articulated by Binford, 1965.
4. 'Material record' subsumes pottery, buildings, metalwork, burial practice and other artifactual evidence.
5. Due early in 1985, R.E. Jones' Greek and Cypriot Pottery (to be published by the British School at Athens) will be the first comprehensive review of scientific techniques applied to finds from the Greek world. Jeffery 1961 offers another avenue of approach, that of dialect analysis.
6. cf. Coldstream 1983:17f. The 'paradox' is clearly due to the equation of a koine (common style) with (a) ease of communication, (b) stability and (c) prosperity, while a diversity of regional styles is equated with (a) ruptured communications, (b) instability and (c) conflict. Coldstream's reinterpretation on political organisation equations does not so much remove the 'paradox' as dilute it. An interesting discussion of the role of communications in general interaction, political systems and stability is given by Cherry 1979.
7. Renfrew 1984:3-9. Binford 1983:19-23.
8. Some deserving orphans amongst them unfortunately. They may also fairly be accused of spoiling a few favourites, such as the 'chiefdom' notion from anthropology, which qualifies for both of these criticisms.
9. The literature is vast; as extensive as various. An adequate recent overview is given by Butzer 1982:212-229, and the inapplicability to the Greek case (at an earlier period, but readily comparable) by Renfrew 1982:281-286, and 1984:24-27. The XTENT model of Renfrew and Level (1979) is the closest, spiritually and methodologically, to that presented here: the differences in question posed, and all that follows thereupon, however, are considerable.

10. cf. Butzer 1982:211, 229, 278, 222, 258. Renfrew 1979:54. See also the more general comments of Renfrew 1982a:29-33.
11. Not only can we not be sure of site size from remains, but calculation of its population is at best a further approximation, with an error margin of 50% considered 'satisfactory' (Hassan 1981:35). A model founded upon size, however measured/estimated, is on precarious ground.
12. Thus demonstrating the value of model building in a historical society as prescribed by, for example, Renfrew 1982b:1-5. Binford 1983:25. Snodgrass 1983:137, 1984:227. Greece is perhaps particularly appropriate because (1) it approximates the abstract 'pristine state' better than many other societies, external influences from 'higher' civilisations being slight; (2) it is relatively well documented; (3) it produced a system which is increasingly believed to be more representative of general societal development than the strongly centralised cultures of antiquity. The model takes as given the concept of 'multiplier effect' (Renfrew 1972).

13. Some sites at which geometric finds have been made were ignored, since the likelihood of anyone living there was considered remote in the extreme, such as Mount Hymettos in Attika. Should any such decision appear illconsidered in the light of new evidence, it is trivially easy to incorporate a site into the data base. In the case of Mount Hymettos this would seem unlikely - the Greek military have blown it up during manoeuvres; Eliot 1976.
14. In each case the exponential function has been used. The question of distance decay is a difficult one, but different rates have been observed for different objects (material) in an investigation by Hodder (1974), and the scope for refinement here is great. We have systematically explored β from 0.9 to 0.05, α from 1.01 to 1.5.

15. Even c.700 an agricultural treatise is distinctly wary of maritime enterprise - Hesiod *Works & Days* 618-694.
16. The smith was probably one, but most people were their own carpenters, potters, weavers, etc.
17. 40,41,42 x 1.5 (island of Euboia). 74,75,76 x 1.5 (Perakhora peninsula). This weighting was applied throughout each analysis.
18. The average polis controlled a territory of ca. 70 square miles. Korinth, a large and powerful polis, controlled ca.350, and Athens' 1000 was exceptionally huge.

19. Hysiai: Hope Simpson 1965:no. 424. Pritchett 1957:22.
Erythrai: Pritchett 1965:104-106. Fossey 1971:106-109.
Skolos: ibid. Pappadakis 1921:523. Pritchett 1965:107-109, 1969: 178-180. Schachter 1981:161.
Herodotus 5.74.2, 6.108 (Hysiai) 9.19.3 (Erythrai) and 9.15.3 (both) implies that these towns are distinguished from Plataia, and Strabo 9.2.24 shows that the question of control was debated even in antiquity.
20. cf. Jamot 1889:407-408; a marker-inscription on their mutual border.
21. Other early examples, Olympia, the Samian Heraion, Kerkyra, Ephesus, all lie outside the survey area. On the Athenian Akropolis cf. Bergquist 1967:23-26.
22. Working with literary evidence Moggi (1976) examined the actual and inferable (?) synoikisms (unions) in Greek history, but literary evidence has its own problems of use and interpretation (Gabba 1983), and badly needs other perspectives in this case (cf. also Roy 1977).
23. cf. for example the problems encountered by Tobler and Wineburg 1971.
24. The analysis has taken as its base Hope Simpson's map (1965), for three main reasons: (1) it is an improvement on the British War Office maps; (2) it is more readily available than either the WO maps or those of the Greek Statistical Service; (3) it is often used by other authors to locate a site under discussion, eg. "Hope Simpson's no. 10", or "just east of HS no. 10". In conjunction with other studies, such as Bintliff 1977, detailed maps of the regions were built up. A simplified version is given in reduced form. (Figure 1).
25. cf. Nandris 1976. The Dacian culture would appear to provide a counterpoint to oppida organisation, and it is surely not irrelevant that Dacian settlements were known to the Greek as poleis.

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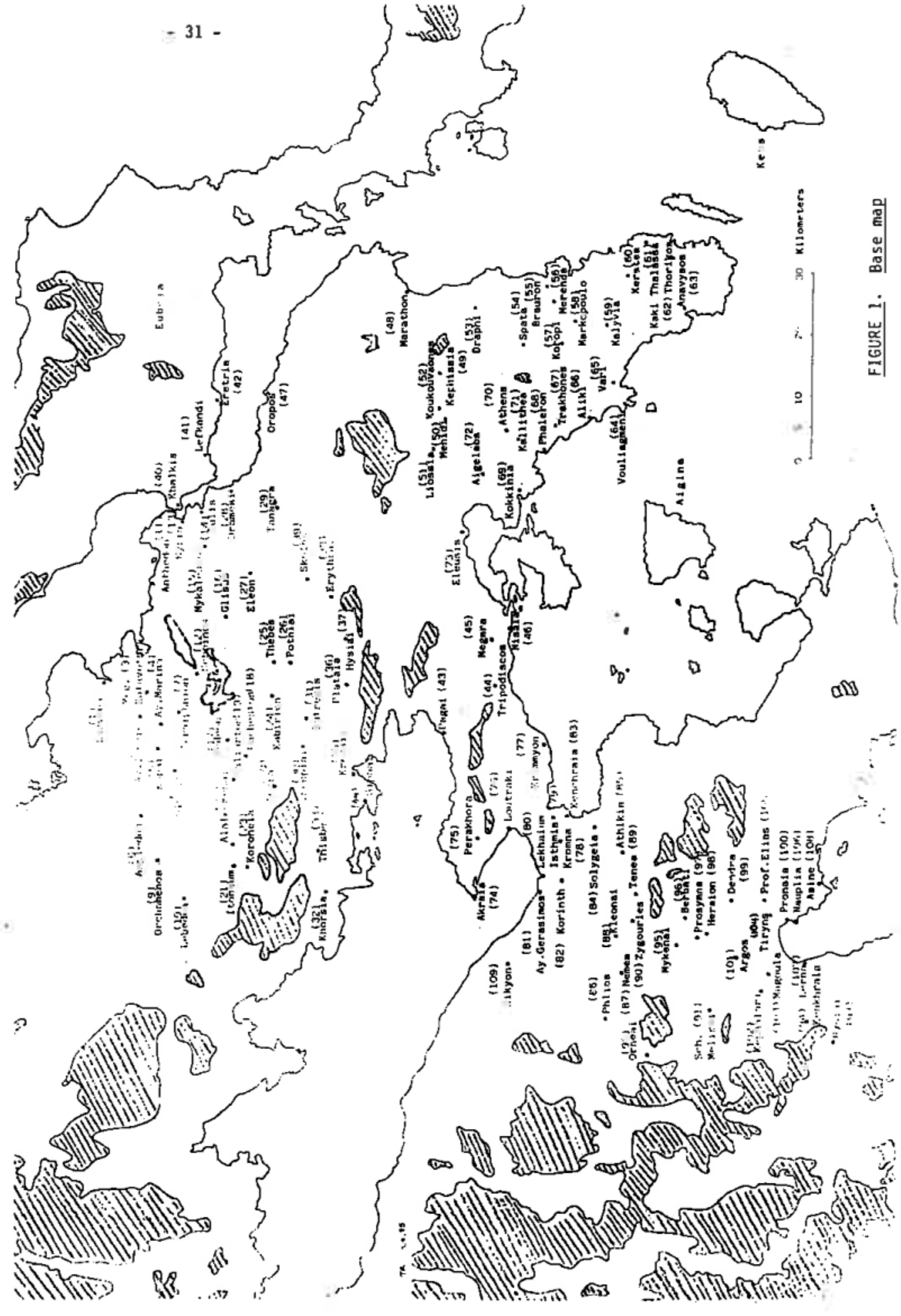
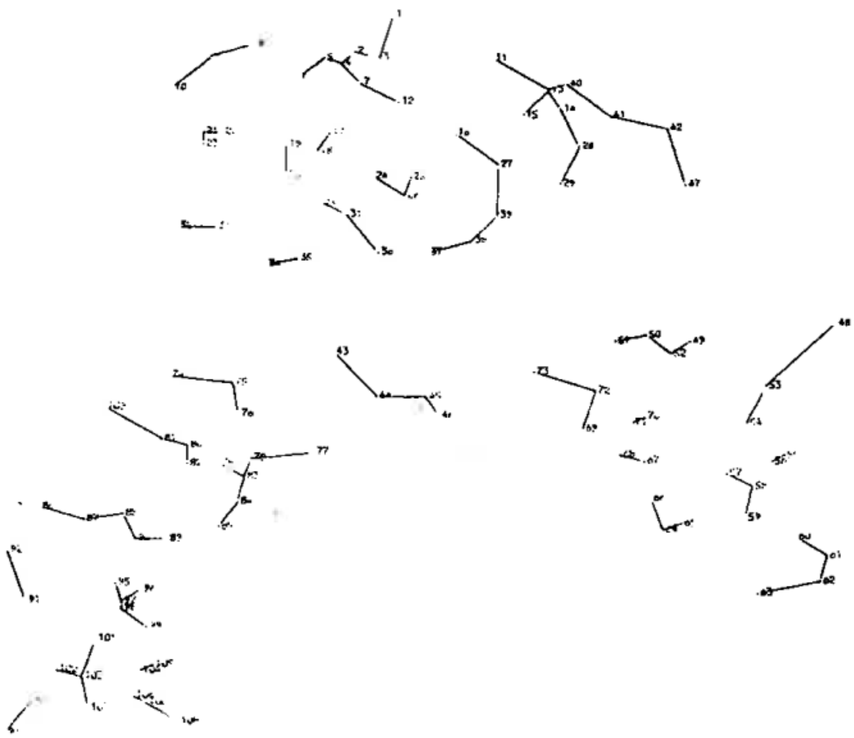


FIGURE 1. Base map

FIGURE 2. Group formation : simple model (1) low-level interaction



Model 1

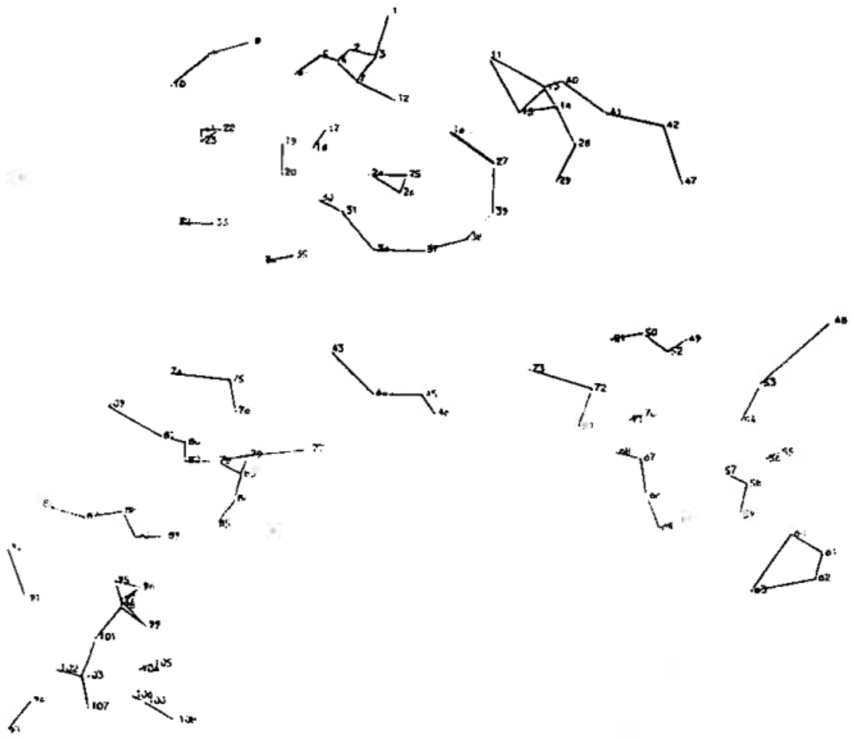
α 1.01
β .9
TND 1

FIGURE 3. Group formation : simple model (1) slightly increased level interaction

Model 1

α 1.01
β .1
TND· 1

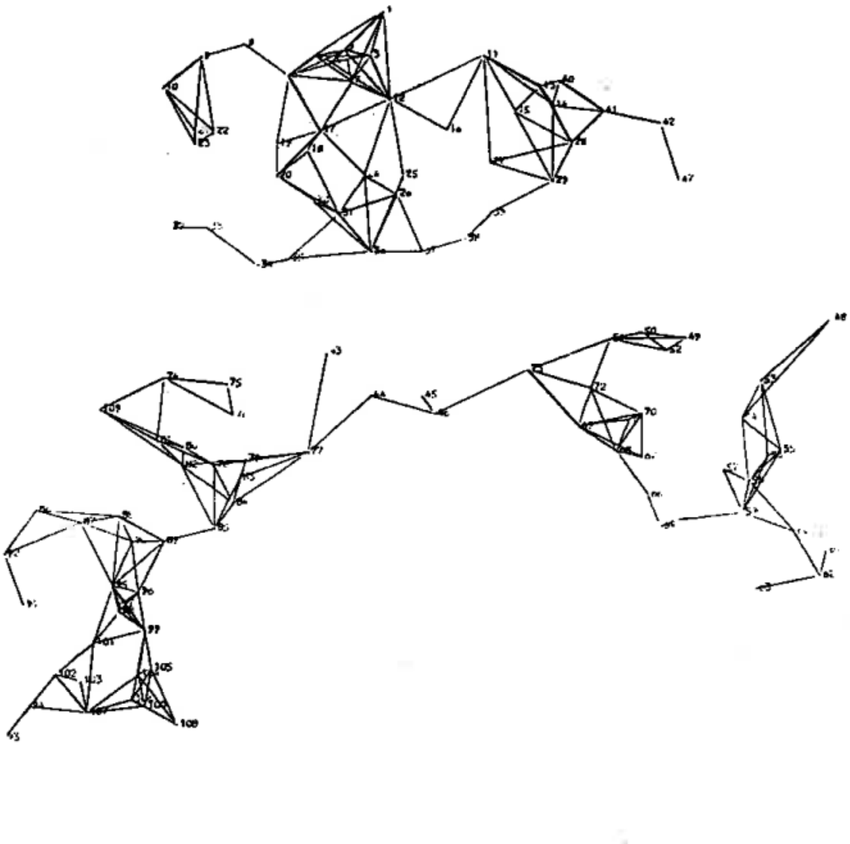
FIGURE 4. Group formation : simple model (1) 50% maximum flows depicted



Model 1

α 1.01
β .9
TND .5

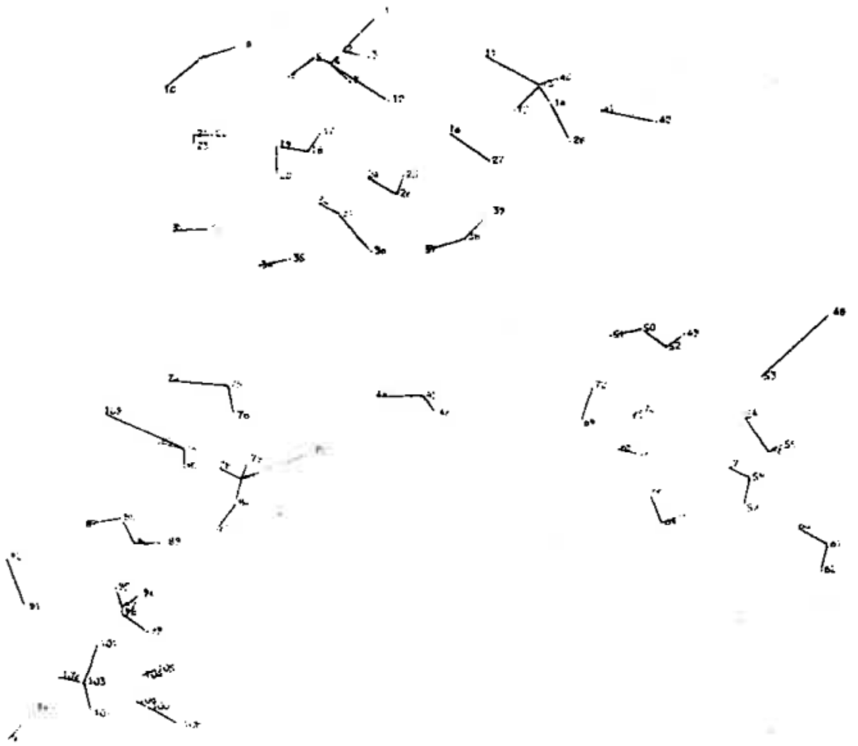
FIGURE 5. Group interaction : simple model (1) 50% maximum flows depicted



Model 1

α 1.01
β .1
TND .5

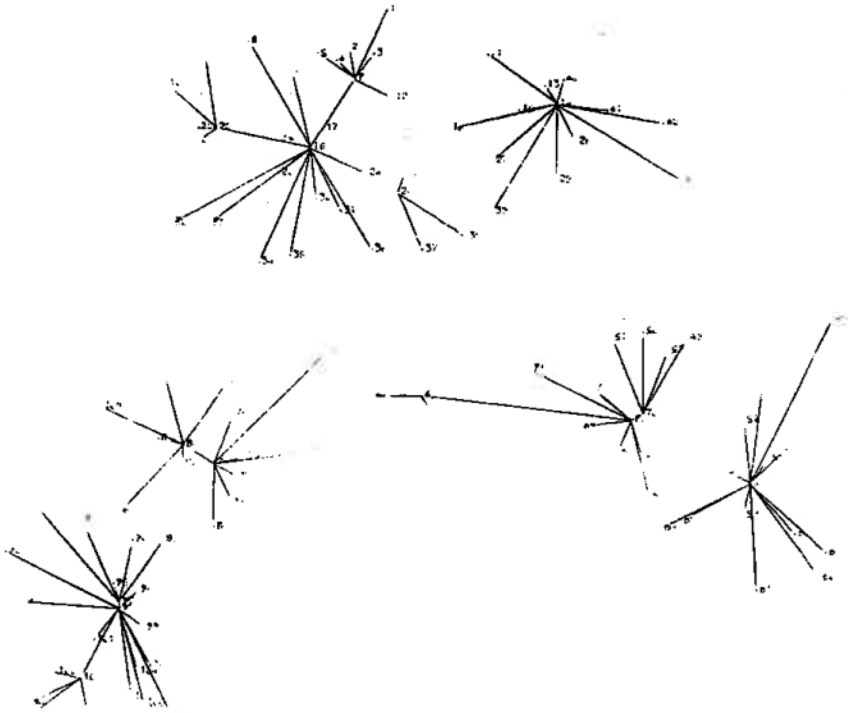
FIGURE 6. Group formation : low level interaction, model 2



Model 2

α	1.01
β	.7
TND	1

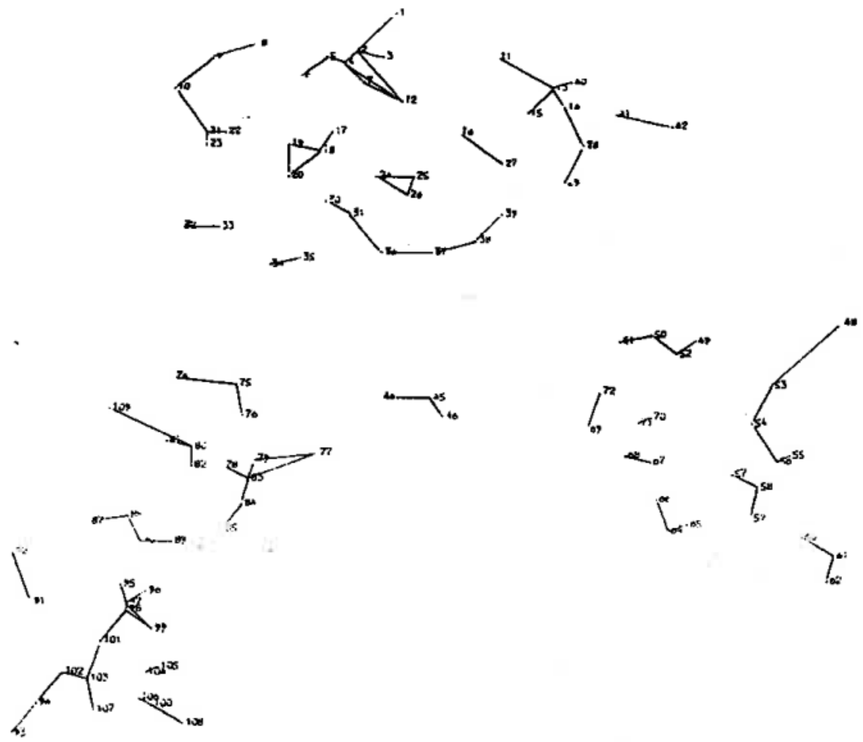
FIGURE 7. Regional foci : group formation : slightly higher level interaction



Model 2

α 1.01
β .1
TND 1

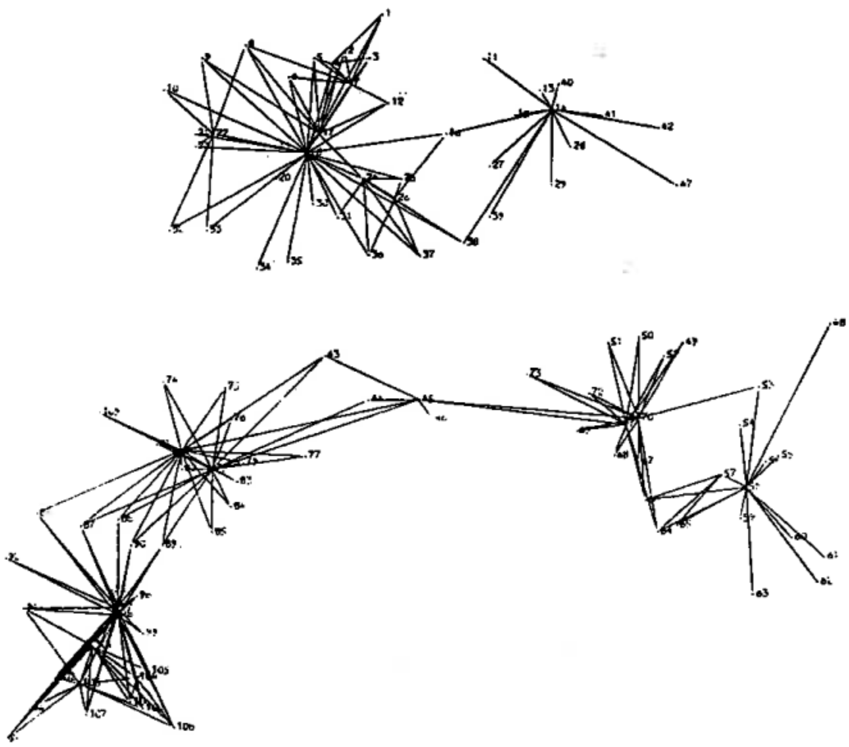
FIGURE 8. Group formation : 50% maximum flows depicted



Model 2

α	1.01
β	.9
TND	.5

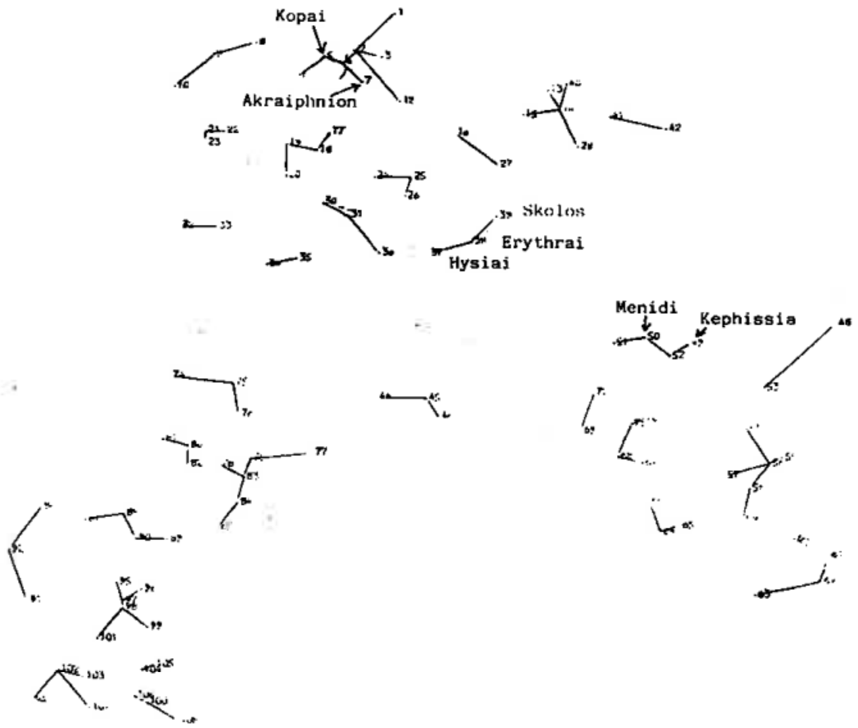
FIGURE 9. Foci interaction : group formation : 50% maximum flow depicted



Model 2

α 1.01
β .1
TND .5

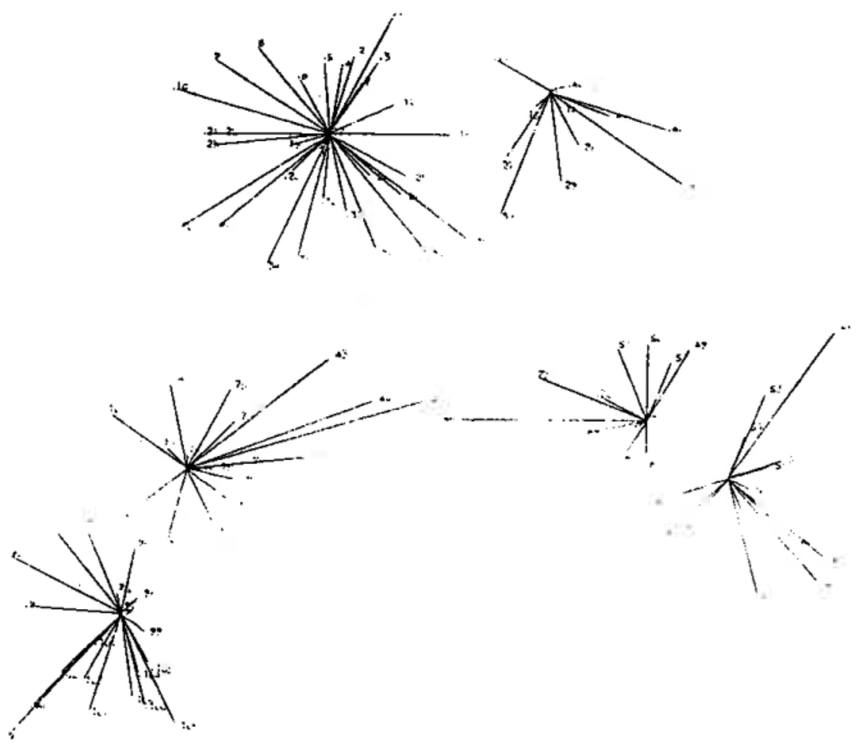
FIGURE 10. Group formation : low level interaction, feedback model



Model 3

α 1.01
β .9
TND 1

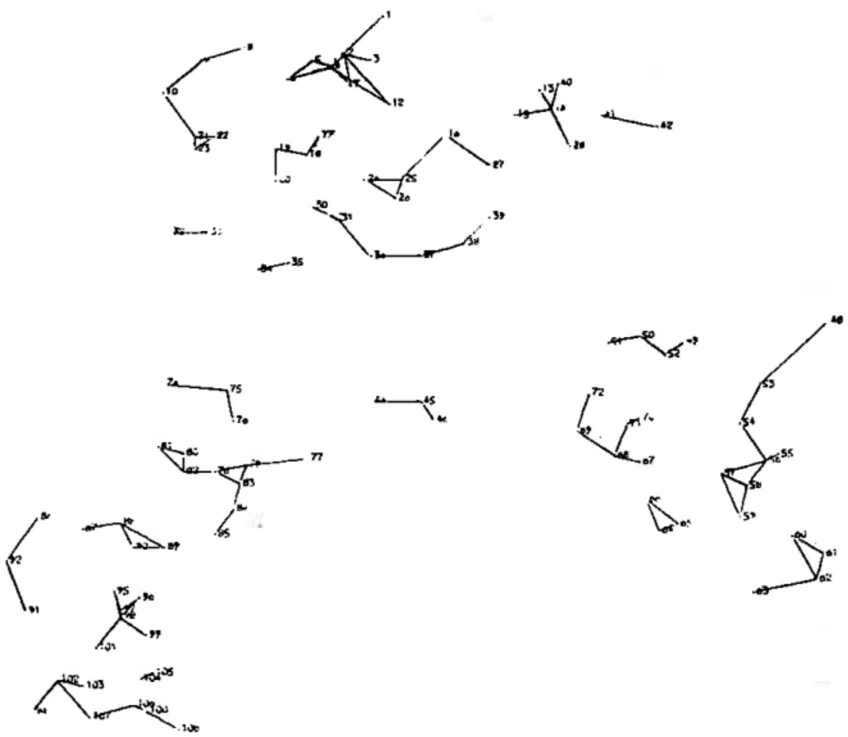
FIGURE 11. Regional foci : group formation : slightly higher interaction



Model 3

α 1.01
β .1
TND 1

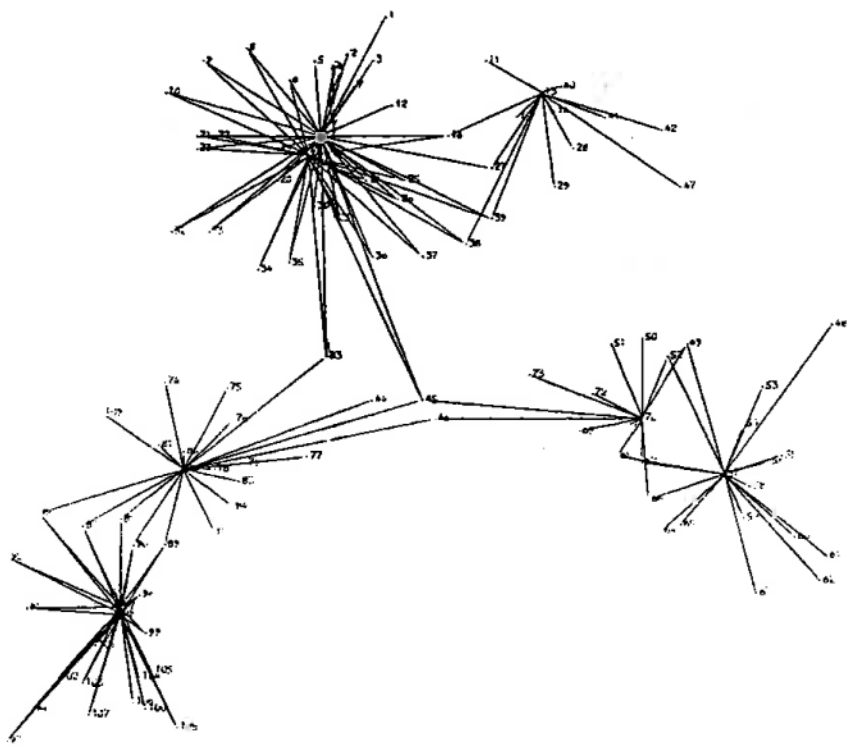
FIGURE 12. Group formation : 50% maximum flows depicted



Model 3

α	1.01
β	.9
TND	.5

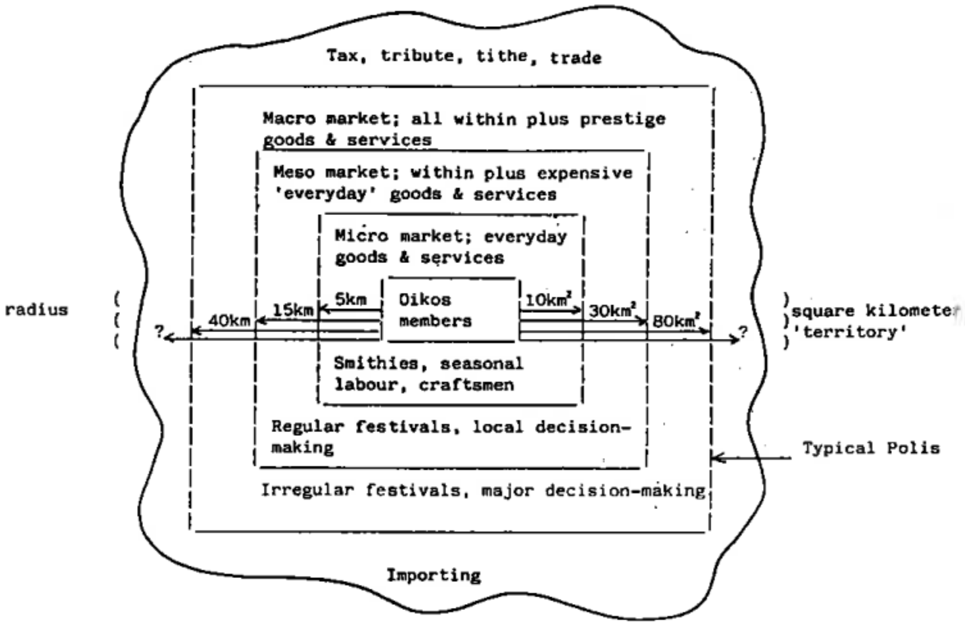
FIGURE 13. Regional foci interaction : group formation : 50% maximum flows depicted



Model 3

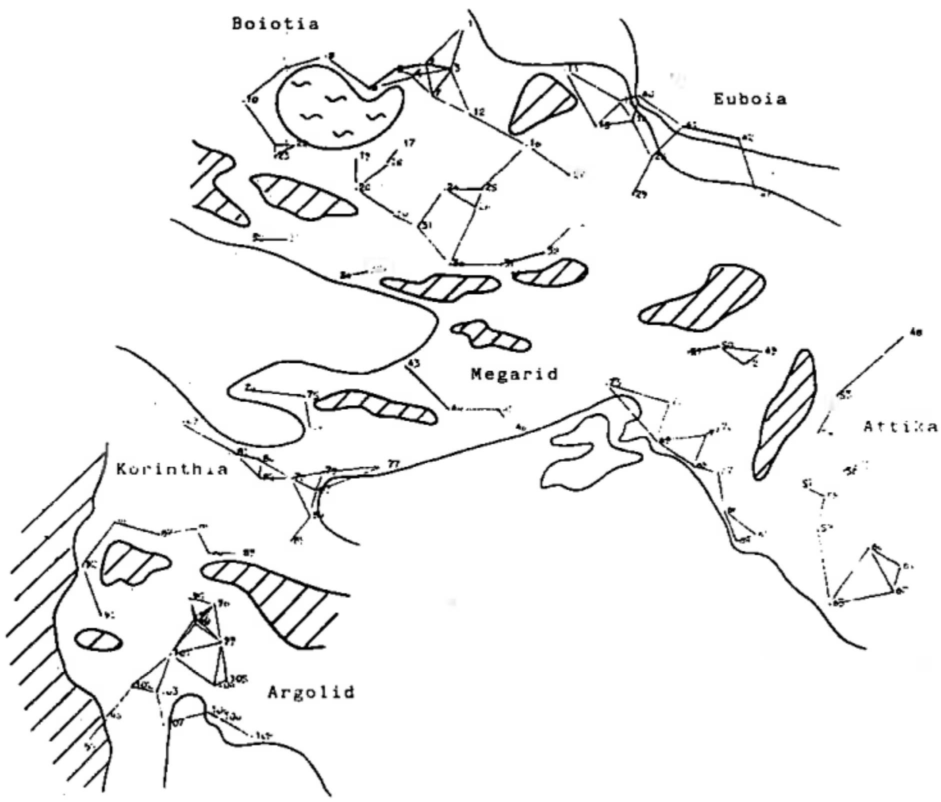
α 1.01
β .1
TND .5

FIGURE 14. Hypothetical model of communication spheres



Decision-making subsumes political, administrative and judicial decisions, including military action. Oikos members includes retainers and slaves.

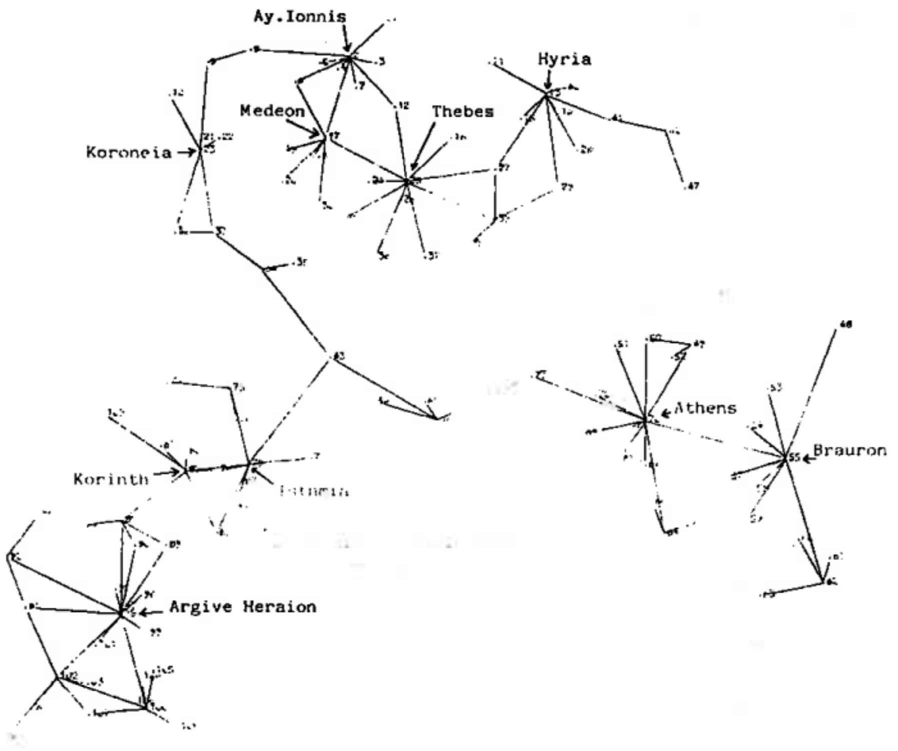
FIGURE 15. The Topography



Model 1

α	1.15
β	.3
TND	.5

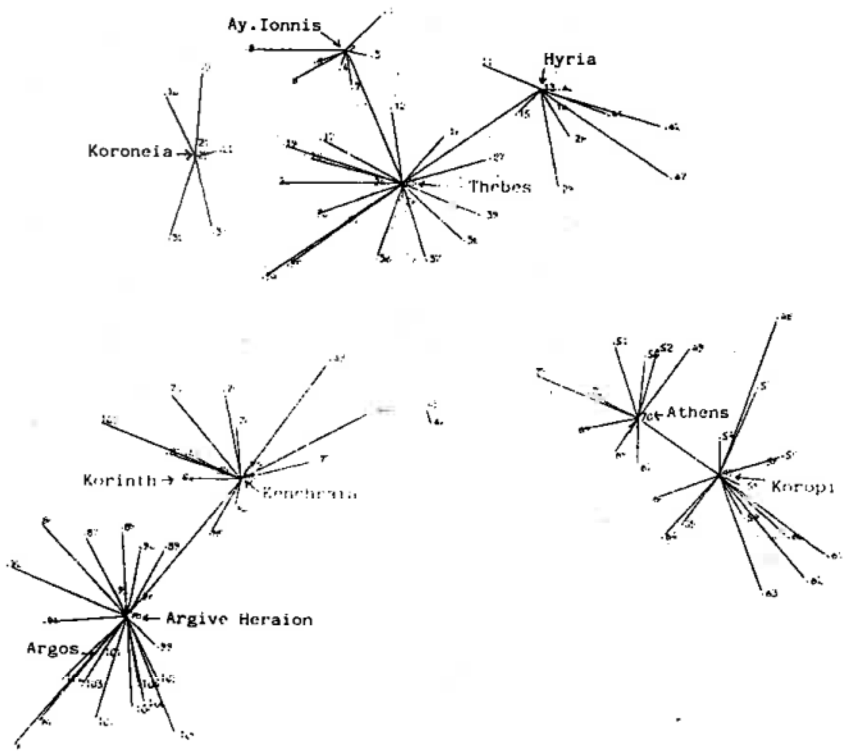
FIGURE 16. The development of centres



Model 3

α	1.15
β	.3
TND	.5

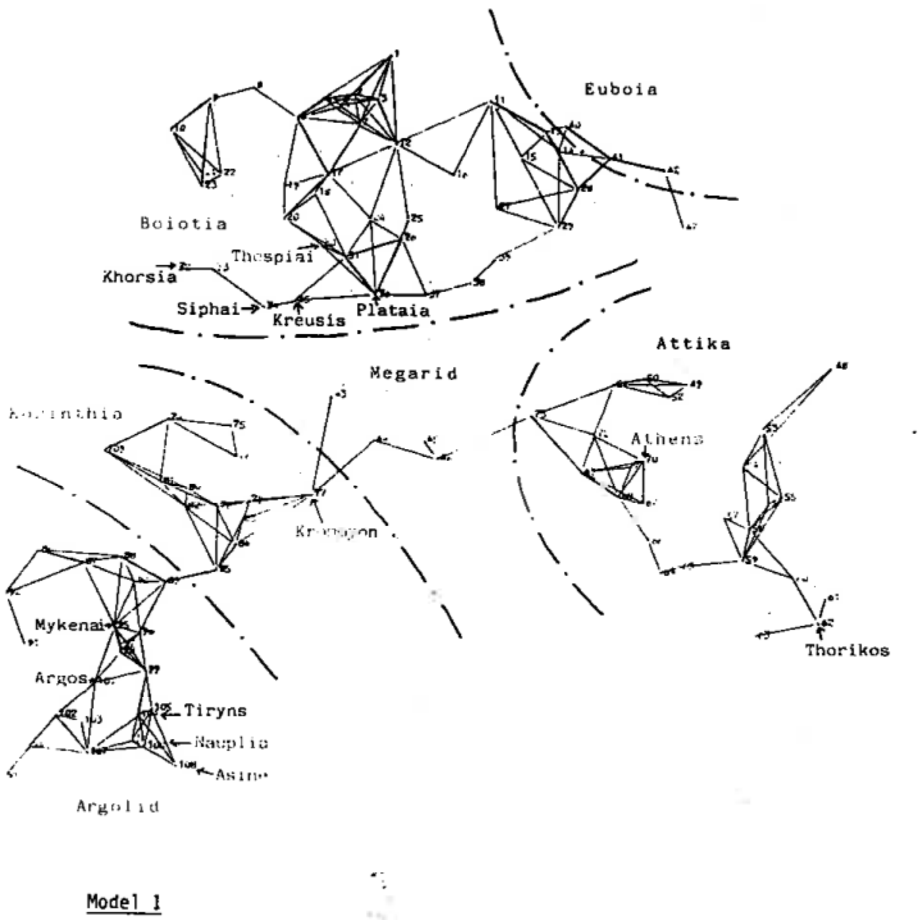
FIGURE 17. The development of centres



Model 3

α 1.5
β .2
TND 1

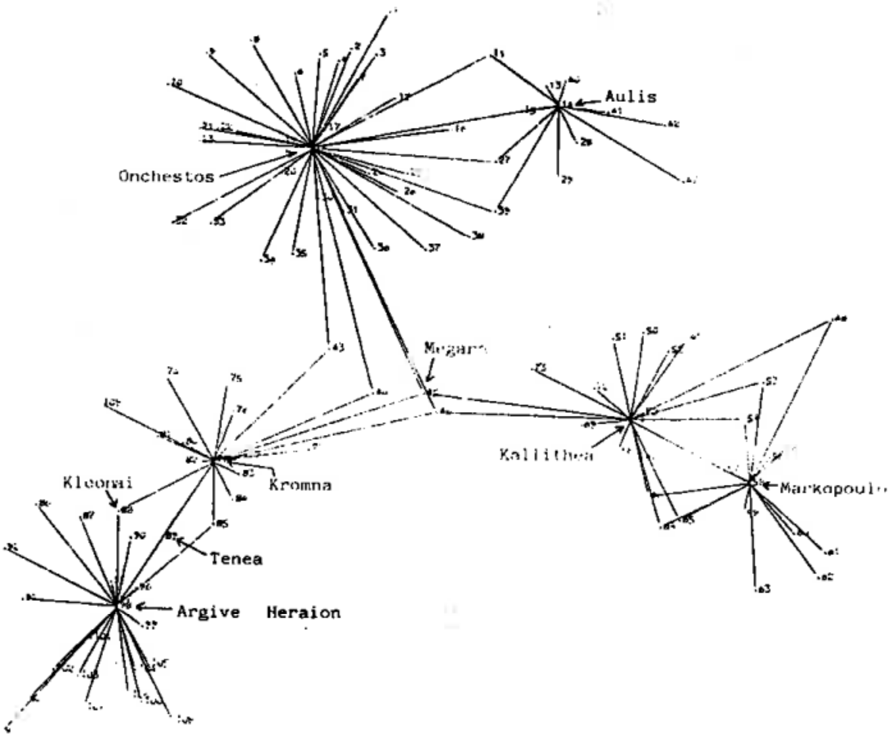
FIGURE 18. Intraregional interaction



Model I

α 1.15
β .1
TND .5

FIGURE 19. Intra- & interregional interaction



Model 2

α 1.15
β .1
TND .5

TABLE 1. Place names and map coordinates

1	Larymna	107,130
2	Ay.Ionnis	101,124
3	Meg.Katavothra	105,123
4	Ay.Marina	100,121
5	Kopai	96,122
6	Olmous	92,119
7	Akraiphnion	102,118
8	Aspledon	85,124
9	Orchomenos	78,121
10	Lebedea	72,117
11	Anthedon	122,122
12	Schoinos	108,115
13	Hyria	132,118
14	Aulis	134,115
15	Mykalessos	128,114
16	Glisas	117,111
17	Medeon	97,110
18	Onchestos	95,107
19	Haliartos	91,109
20	Askra	90,103
21	Itoneum	77,109
22	Alalkomenai	81,108
23	Koroneia	77,107
24	Kabirion	105,103
25	Thebes	110,103
26	Potniai	110,100
27	Eleon	124,107
28	Dramesi	13[illegible],110
29	Tanagra	135,102
30	Thespiai	96,98
31	Eutresis	101,97
32	Khorsia	73,94
33	Thisbe	80,95
34	Siphai	88,88
35	Kreusis	92,90
36	Plataia	106,91
37	Hysiai	114,91
38	Erythrai	120,94
39	Skolos	123,98
40	Khalkis	135,118
41	Lefkandi	143,114
42	Eretria	152,112
43	Pagai	99,75
44	Tripodiscos	106,67
45	Megara	114,68
46	Nisaia	115,65
47	Oropos	153,104
48	Marathon	170,82
49	Kephissia	156,77
50	Menidi	149,76
51	Liossia	144,78
52	Koukouvaones	151,77
53	Draphi	167,71
54	Spata	161,63
55	Brauron	171,60
56	Merenda	168,59
57	Koropi	161,57
58	Markopoulo	165,55
59	Kalyvia	165,50
60	Keratea	172,47
61	Kaki Thalassa	178,44
62	Thorikos	175,40
63	Anavysos	168,38
64	Vouliagmeni	152,47
65	Vari	155,49
66	Aliki	150,53
67	Trakhones	148,58
68	Phaleron	144,60
69	Kokkinia	138,64
70	Athens	148,66
71	Kallithea	146,64
72	Aigelaos	140,70
73	Eleusis	131,73
74	Akraia	73,70
75	Perakhora	82,70
76	Loutraki	84,65
77	Krommyon	97,59
78	Kromna	81,57
79	Isthmia	86,58
80	Lekhaion	76,60
81	Ay.Gerasimos	73,60
82	Korinth	75,56
83	Kenchraia	85,56
84	Solygeia	84,51
85	Athikia	80,47
86	Phlios	53,49
87	Nemea	60,47
88	Kleonai	66,48
89	Tenea	73,45
90	Zygouries	69,45
91	Sch.Melissi	54,33
92	Orneai	48,42
93	Hysiai	49,13
94	Kenkhraia	53,17
95	Mykenai	65,38
96	Berbati	69,37
97	Prosymna	66,35
98	Heraion	67,34
99	Dendra	72,29
100	Pronaia	70,20
101	Argos	63,28
102	Kephalari	57,24
103	Magoula	60,23
104	Tiryns	69,23
105	Prof.Elias	72,24
106	Nauplia	68,19
107	Lerna	62,17
108	Asine	75,15
109	Sikyon	62,65

Names should be treated as labels; in many instances identification is uncertain.

TABLE 2. Accessibilities (line 1, β = 0.9, line 2, β = 0.1

Zone	To G_i	To W_j	To W_j^F
1	0.0131 4.4388	0.1138 39.9628	0.1044 40.1023
2	0.1350 6.8757	2.8082 77.6388	2.4799 78.1411
3	0.0537 6.6232	0.5917 73.4927	0.9347 74.7026
4	0.1753 7.3609	2.3042 86.4320	3.0326 97.7812
5	0.0924 6.8383	2.1423 79.9414	1.9072 89.9400
6	0.0245 6.7257	0.1705 84.2475	0.0818 108.8288
7	0.0586 7.5349	0.9237 96.4344	0.9489 116.8151
8	0.0130 4.7741	0.1276 44.3872	0.1256 49.7011
9	0.0135 4.2379	0.1366 35.1216	0.1404 34.5803
10	0.0126 3.8319	0.1191 30.8913	0.1081 25.6887
11	0.0113 4.2693	0.1117 44.4545	0.1090 54.1862
12	0.0148 6.8242	0.1164 86.2417	0.1116 97.8074
13	0.0704 5.2737	0.8201 79.6702	1.7119 77.4158
14	0.0605 5.4384	1.3043 75.2237	0.6744 82.7675
15	0.0220 5.6146	0.2412 73.2343	0.2142 76.2691
16	0.0118 6.1168	0.1166 66.1471	0.1147 63.7582
17	0.0522 7.8714	1.0550 141.3910	0.6083 212.0696
18	0.0643 7.9045	0.5178 140.2249	1.1604 217.5870

TABLE 2 (contd)

Zone	To G_i	To W_j	To W_j^F
19	0.0340 7.3636	0.3891 123.4932	0.1834 173.3959
20	0.00271 7.1364	0.2175 113.4896	0.1144 143.5796
21	0.2441 5.6588	2.2575 60.2136	3.2633 48.4421
22	0.1175 6.0797	1.7194 68.4873	1.5740 64.9001
23	0.1255 5.6104	3.1773 60.3787	2.2755 48.8643
24	0.0230 7.5923	0.1758 117.9072	0.1670 131.2857
25	0.0739 7.1619	1.0410 98.0236	0.9560 86.2187
26	0.0750 7.1384	0.9325 94.6467	1.1012 80.9913
27	0.0127 5.7829	0.1231 57.8772	0.1205 48.9829
28	0.0162 4.8654	0.1399 68.5139	0.1409 50.2944
29	0.0137 4.6814	0.1352 52.2433	0.1331 36.7309
30	0.0318 7.2873	0.3563 109.4983	0.3276 128.4816
31	0.0318 7.1258	0.3193 99.5686	0.3617 101.9922
32	0.0156 3.7562	0.1557 29.0058	0.1547 26.3691
33	0.0158 4.7386	0.1578 41.9655	0.1583 40.7282
34	0.0214 5.0582	0.2139 45.3451	0.2136 44.2533
35	0.0215 5.5881	0.2148 55.8173	0.2149 54.4596
36	0.0129 5.9166	0.1222 63.5201	0.1113 52.7195

TABLE 2 (contd)

Zone	To G_i	To W_j	To W_j^F
37	0.0135 5.5291	0.1288 50.9704	0.1203 37.7621
38	0.0187 5.2805	0.1990 42.8947	0.2187 31.5076
39	0.0181 5.3164	0.1810 44.4297	0.1776 33.5454
40	0.0294 3.4098	0.4644 52.9135	0.2386 66.7878
41	0.0119 2.8354	0.1153 34.7787	0.1150 24.3430
42	0.0114 1.8441	0.1136 9.7085	0.1135 6.3200
43	0.0112 4.1062	0.1124 30.9480	0.1125 23.0024
44	0.0121 3.8492	0.1144 28.1963	0.1068 16.2667
45	0.0508 3.8068	0.4943 27.9561	0.5616 14.6964
46	0.0502 3.5378	0.5479 28.6581	0.5091 14.1467
47	0.0111 2.3654	0.1111 18.1730	0.1111 13.6466
48	0.0111 1.9030	0.1111 12.1163	0.1111 12.0952
49	0.0518 4.7932	0.7782 47.3623	0.6834 48.6444
50	0.0341 5.0849	0.4014 48.5144	0.3054 48.5215
51	0.0220 4.9899	0.1909 47.9790	0.1342 47.8417
52	0.0615 5.4141	0.5227 58.0740	0.8403 61.7182
53	0.0136 4.2885	0.1338 44.3802	0.1362 48.1517
54	0.0165 5.5285	0.1396 73.5417	0.1110 84.3516

TABLE 2 (contd)

Zone	To G_i	To W_j	To W_j^F
55	0.1476 5.3084	2.3471 73.2894	4.0254 67.2487
56	0.1590 5.8075	1.5877 87.0137	2.6606 82.8658
57	0.0322 6.2509	0.5148 104.0086	0.1688 110.7713
58	0.0522 6.1182	0.5099 95.5155	0.5288 105.4038
59	0.0231 5.5507	0.2838 84.9432	0.0288 78.8818
60	0.0177 4.4953	0.1578 48.3525	0.0434 37.9879
61	0.0408 3.6136	0.3709 28.4316	0.6775 21.3800
62	0.0364 3.3026	0.6136 22.8843	0.3861 17.4740
63	0.0113 3.3123	0.1117 28.1582	0.1114 24.3863
64	0.0771 4.9555	0.7718 50.5094	1.2509 57.8492
65	0.0726 5.3601	1.1474 60.5364	0.7028 69.7444
66	0.0268 5.6108	0.2204 65.1737	0.1479 75.9042
67	0.0451 6.2981	0.4096 91.7747	0.3860 104.6964
68	0.0470 6.0100	0.4839 86.6265	0.3681 93.5705
69	0.0169 5.1710	0.1514 63.5873	0.1300 65.2654
70	0.1486 6.4881	2.3191 110.5466	2.3605 117.0698
71	0.1576 6.5338	1.5813 107.9891	2.5915 125.2104
72	0.0163 5.5183	0.1501 67.9165	0.1331 70.0097

TABLE 2 (contd)

Zone	To G_i	To W_j	To W_j^F
73	0.0112 3.9812	0.1119 32.6580	0.1117 28.8838
74	0.0112 2.5404	0.1118 21.3788	0.1111 19.5229
75	0.0214 2.9796	0.2148 24.4552	0.2149 18.5492
76	0.0214 3.6307	0.2133 41.9355	0.2142 30.4670
77	0.0113 4.0980	0.1112 38.9422	0.1102 29.3273
78	0.0582 6.9750	0.8039 105.9510	0.9096 111.5471
79	0.0812 6.2670	1.6840 87.0442	1.3528 70.3452
80	0.1083 6.6833	0.9784 105.2028	1.7528 131.6446
81	0.0420 5.9691	0.6078 92.5359	0.3582 104.7845
82	0.0961 6.9415	1.6141 118.8627	0.8477 115.3393
83	0.1122 6.5079	0.8603 92.5045	1.7625 78.1388
84	0.0507 6.2466	0.8675 81.3744	0.5317 78.3822
85	0.0233 6.1090	0.1881 74.5444	0.0524 83.3662
86	0.0130 4.2663	0.1292 35.3752	0.1266 43.5029
87	0.0173 5.9055	0.1367 59.4718	0.1699 75.4484
88	0.0340 6.6928	0.5499 73.4033	0.4526 95.3865
89	0.0240 7.0312	0.2857 84.7401	0.0612 108.1185
90	0.0425 7.3472	0.4225 87.0477	0.6749 112.8046

TABLE 2 (contd)

Zone	To G_i	To W_j	To W_j^F
91	0.0116 4.8222	0.1156 52.8204	0.1152 55.2674
92	0.0120 3.8742	0.1200 32.5081	0.1199 37.1803
93	0.0143 3.1236	0.1398 22.7255	0.1317 15.6845
94	0.0180 4.6336	0.1522 42.2847	0.1758 29.7079
95	0.1200 7.9793	2.3636 128.9699	2.1410 170.2802
96	0.1018 7.9811	1.7191 127.3618	1.6056 167.6927
97	0.5226 8.4253	10.0788 142.0914	12.6706 186.3338
98	0.4786 8.3967	12.5280 141.8852	10.0697 175.2868
99	0.0396 7.6684	0.5067 117.5690	0.5344 141.7328
100	0.1648 6.2502	1.9815 60.0852±	3.4279 48.7629
101	0.0216 7.5613	0.2331 116.0831	0.1757 120.3013
102	0.0405 6.1376	0.8014 74.9705	0.4593 56.2112
103	0.0503 6.8548	0.4757 83.0130	0.9942 65.4017
104	0.1822 7.4048	1.6763 85.9483	1.8216 80.7793
105	0.1589 7.1110	1.8449 86.0209	1.4414 82.7861
106	0.1772 6.7419	2.9316 69.4812	2.2059 55.6860
107	0.0244 5.8545	0.3299 62.5273	0.0796 42.7041
108	0.0173 4.3408	0.1287 36.9619	0.0854 31.3398
109	0.0112 3.6344	0.1113 37.6395	0.1112 42.8523

TABLE 3. Distributions of size/"importance"

Zone	$\beta = .9$ W_j Revenue	$\beta = .9$ W_j^F	$\beta = .1$ W_j	$\beta = .1$ W_j^F
1	9.29	7.92	0.00	0.00
2	17.09	31.88	0.59	0.00
3	0.56	0.02	0.09	0.00
4	31.64	26.57	19.35	0.00
5	9.88	3.63	0.52	0.00
6	0.71	0.00	0.77	0.00
7	0.75	0.11	31.60	0.00
8	10.09	9.90	0.00	0.00
9	10.25	10.68	0.00	0.00
10	9.08	8.23	0.00	0.00
11	9.80	9.74	0.00	0.00
12	9.81	9.50	0.16	0.00
13	29.03	5.61	0.80	86.79
14	12.74	41.80	84.19	21.17
15	0.37	0.00	0.97	0.53
16	9.85	9.65	0.06	0.00
17	3.88	25.89	38.99	189.49
18	24.93	7.94	68.41	126.63
19	7.72	4.82	22.35	0.95
20	3.65	1.03	9.65	0.02
21	18.38	12.43	4.63	0.00
22	0.08	0.24	27.28	0.00
23	12.33	18.76	1.85	0.00
24	1.13	0.00	26.75	12.00
25	12.90	16.33	14.74	0.19
26	15.18	13.31	27.40	0.04
27	9.95	9.83	1.25	0.00
28	7.35	1.21	24.75	0.83
29	10.42	11.50	0.02	0.00
30	9.21	13.68	14.66	0.02
31	12.63	9.34	10.75	0.00
32	9.93	9.80	0.00	0.00
33	10.04	10.14	0.00	0.00
34	10.02	10.03	0.00	0.00
35	9.96	9.93	0.09	0.00
36	9.14	8.50	0.16	0.00
37	9.28	8.23	0.12	0.00
38	11.52	14.32	0.10	0.00
39	9.24	7.46	0.17	0.00
40	0.11	0.01	0.00	0.00
41	10.08	10.04	0.03	0.00
42	10.00	9.99	0.10	0.00
43	10.01	10.02	0.01	0.00
44	9.34	8.75	0.82	0.00
45	11.37	9.79	19.32	0.01
46	9.29	11.44	0.19	1.49
47	10.00	10.00	0.00	0.00
48	10.00	10.00	0.00	0.00
49	4.52	14.69	0.03	0.00
50	13.47	11.27	0.48	0.00
51	3.93	1.01	0.08	0.00
52	17.99	12.85	6.85	0.00
53	10.42	11.67	0.00	0.00

TABLE 3 (contd)

Zone	β = .9 W_j Revenue	W_j^F	β = .1 W_j	W_j^F
54	7.16	1.99	0.68	0.00
55	8.30	17.35	0.08	0.00
56	16.44	28.11	6.12	0.05
57	0.76	9.50	33.07	132.72
58	26.22	1.20	79.54	5.30
59	0.73	0.21	6.81	0.03
60	3.17	0.31	4.47	0.00
61	22.15	4.23	0.02	0.00
62	4.62	25.55	0.00	0.00
63	9.97	9.79	0.00	0.00
64	17.60	8.30	0.00	0.00
65	9.84	19.91	0.02	0.00
66	0.86	0.00	0.01	0.00
67	9.11	3.85	2.20	0.02
68	9.42	10.33	0.16	0.00
69	8.43	6.68	0.00	0.00
70	9.60	17.28	59.79	95.02
71	16.26	15.96	61.30	38.04
72	9.05	7.98	0.82	0.00
73	9.99	9.99	0.00	0.00
74	9.94	9.88	0.00	0.00
75	10.34	10.53	0.00	0.00
76	9.71	9.51	0.00	0.00
77	9.90	9.60	0.00	0.00
78	0.22	0.21	71.65	2.74
79	3.51	24.82	6.28	0.00
80	22.00	8.40	65.48	0.68
81	0.07	0.01	0.37	0.00
82	10.84	24.57	12.48	153.28
83	27.79	18.11	0.76	0.02
84	14.05	4.32	0.00	0.00
85	1.62	0.02	0.00	0.00
86	10.30	10.91	0.00	0.00
87	7.04	0.49	0.00	0.00
88	8.04	34.77	0.07	0.00
89	1.10	0.10	0.01	0.00
90	23.62	3.73	0.66	0.00
91	9.97	9.89	0.00	0.00
92	9.98	9.96	0.00	0.00
93	10.16	11.29	0.00	0.00
94	8.35	1.65	0.00	0.00
95	0.01	0.00	8.91	0.48
96	0.01	0.00	1.22	0.32
97	30.16	23.93	59.80	93.38
98	23.93	30.51	63.89	125.59
99	0.00	0.00	0.38	0.10
100	17.91	12.62	0.02	0.00
101	0.24	0.00	30.58	2.34
102	6.09	39.32	0.85	0.00
103	28.38	0.79	33.42	0.00
104	12.10	8.80	14.89	0.00
105	7.91	7.60	0.33	0.00
106	12.08	23.66	1.68	0.00
107	0.39	0.01	0.03	0.00
108	2.20	0.00	0.00	0.00
109	10.01	10.01	0.00	0.00