*Hage, Per, Frank Harary and David Krackhardt
1998 "A Test of Communication and Cultural Similarity in Polynesian Prehistory." Current Anthropology, 39(5):699-703.

Reports

A Test of Communication and Cultural Similarity in Polynesian Prehistory[1]

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In every field of anthropology one comes up against the problem of determining whether two (or more) networks defined by different relations over the same set of groups or individuals are significantly correlated. The networks may be defined by relations, say, of genetic similarity and geographical distance between pairs of villages, kinship distance and exchange transactions between pairs of individuals, or lexical differentiation and spatial distance between pairs of languages. Such networks can be correlated, but the problem is to find a test of statistical significance. The solution is to use a powerful statistical method invented in medical research known as the Mantel test (Mantel 1967) and more recently as the quadratic assignment procedure (Hubert 1987). Our purpose is to show how this method can be used to test network hypotheses in archaeology.[2]

In an innovative and influential contribution to Oceanic archaeology, Irwin (1992) proposes that the prehistoric exploration and colonization of the Pacific Islands was rapid, purposeful, and systematic. Irwin's study is timely given the accelerating growth of knowledge in Pacific prehistory (Allen 1994, Bahn 1993, Green 1993, Thorne 1993) and the increasing recognition that most islands in the Pacific were joined in various types of social and linguistic networks (Hage and Harary 1996, Kirch 1988). Drawing on computer simulations, studies of experimental voyaging, and practical sailing experience, Irwin argues that early voyagers in the Pacific adopted a cautious strategy of exploring first upwind in order to ensure a safe return to their point of departure. By this he means sailing east using summer and winter westerlies and returning west with the resumption of the prevailing easterly tradewinds. Then, with improving navigational skills and expanding geographical knowledge, they sailed across the wind and, finally, riskiest of all, downwind. In general, the archaeological evidence supports the hypothesis that islands from which it was easiest to return were settled first.

Irwin also hypothesizes that island communities did not necessarily become isolated after settlement but remained in communication and, depending on their degree of "mutual accessibility," continued to influence each other. Mutual accessibility is defined as the product of closeness and angle of target size between island pairs. In support of his hypothesis, Irwin generates an interisland accessibility network which he then compares with networks showing the cultural, linguistic, and biological similarity between pairs of islands in Polynesia. The cultural network consists of a mapping of Polynesia into cultural areas as drawn by Burrows (1938): the linguistic network is a phylogenetic tree of the Polynesian languages, and the biological network is a dendrogram showing the similarity between populations based on shared physical traits (Pietrusewsky 1971, Howells 1979). Irwin sees "close correspondences" between accessibility and all three of these networks. These correspondences contradict the traditional view of "islands as laboratories in which the inhabitants worked out their human inheritance alone, in a range of different circumstances" (Irwin 1992:206). They would, for example, support the idea, derived from Renfrew and Cherry's (1986) peer polity interaction model, that social stratification in eastern Polynesia was the result of elite interaction in a network of societies rather than a modification of an already stratified ancestral Polynesian society as hypothesized by Kirch and Green (1987).

There is a serious difficulty with Irwin's analysis because he has no method for comparing these networks. All that can be said is that the networks appear to correspond, but we really do not know if accessibility has a statistically significant relation to cultural, linguistic, and biological similarity. To appreciate the problem, one may compare Irwin's network of interisland accessibility in figure 1 (the higher the numbers on the lines, the greater the accessibility between island pairs) with Burrows's diagram of culture areas in Polynesia in figure 2.[3] How significant is the match? It is difficult to say.

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2. Applications to cultural anthropology include Nakao and Romney's (1984) test of competing cognitive models of kinship classification and Schweizer's (1997) analysis of embeddedness in gift-giving networks. For applications to physical anthropology see Dow and Cheverud (1985) and Smouse and Long (1992). An application to primate studies is given in Schnell, Watt, and Douglas (1985).

3. The islands in figure 1 are a subset of those in figure 2. Tongarava, Rakahanga, and Manihiki in figure 2 are included in the Northern Cooks in figure 1.

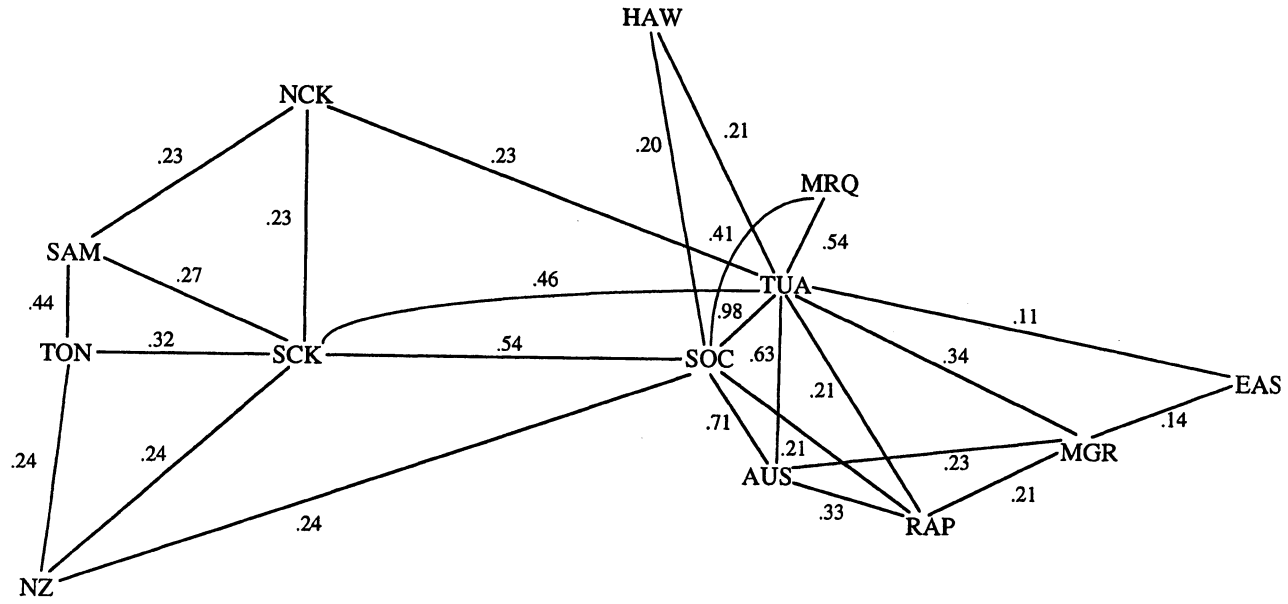

FIG. 1. *Irwin's (1992) mutual accessibility network of Polynesian islands.* TON, *Tonga;* SAM, *Samoa;* SCK, *Southern Cooks;* NCK, *Northern Cooks (Tongareva, Rakahanga-Manihiki, Pukapuka):* SOC, *Society Islands;* MRQ, *Marquesas;* TUA, *Tuamotus;* MGR, *Mangareva;* AUS, *Australs;* RAP, *Rapa;* HAW, *Hawaii;* EAS, *Easter;* NZ, *New Zealand.*

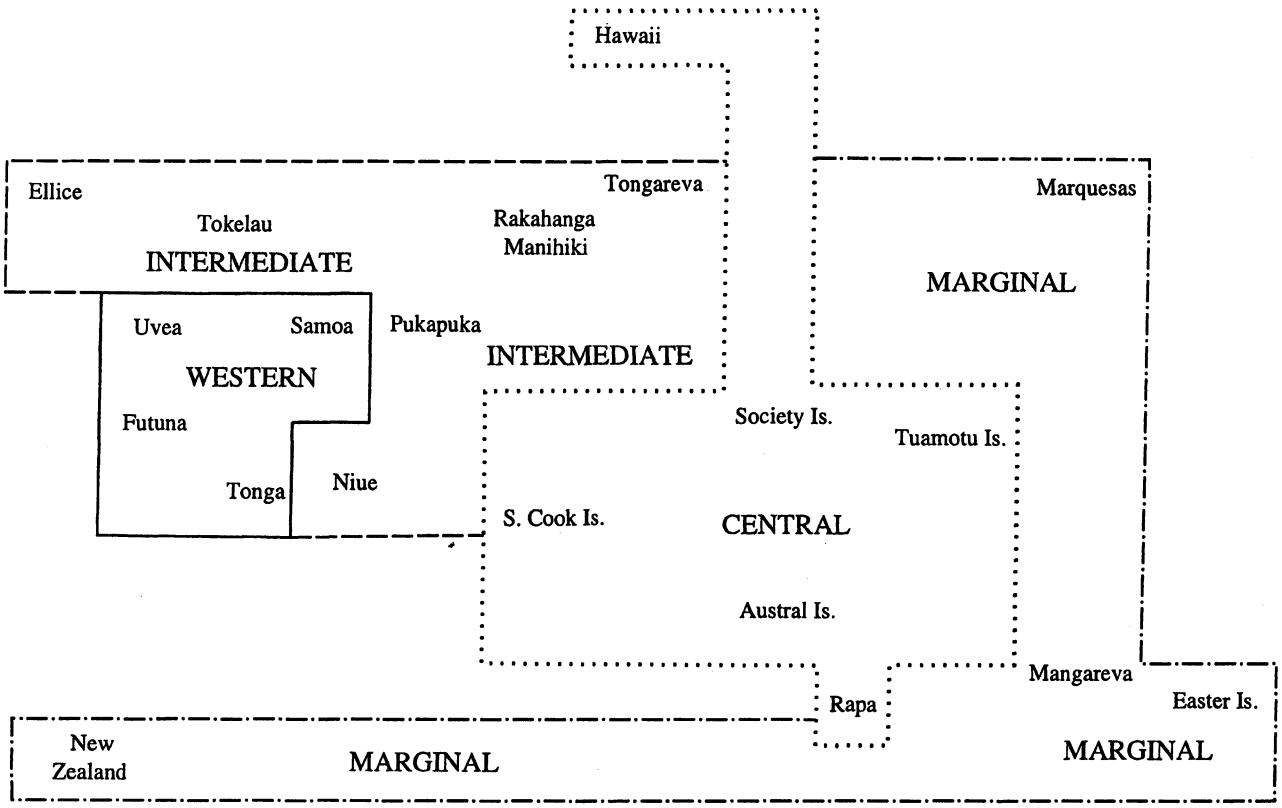

FIG. 2. *Burrows's (1938) distribution diagram of cultural groupings in Polynesia.*

TABLE 1
Cultural Similarity and Minimum Accessibility Matrices for Polynesia Based on Burrows (1938) and Irwin (1992)

	TON	SAM	SCK	NCK	SOC	MRQ	TUA	MGR	AUS	RAP	HAW	EAS	NZ
Tonga (TON)		2	16	8	15	18	17	19	16	18	19	19	17
Samoa (SAM)	.56		16	9	16	18	17	18	18	19	19	19	17
Southern Cooks (SCK)	.68	.73		8	3	7	6	10	9	10	8	14	9
Northern Cooks (NCK)	.82	.77	.77		9	11	9	12	11	14	13	15	12
Society (SOC)	.78	.83	.46	.77		4	3	8	9	8	6	12	6
Marquesas (MRQ)	.82	.85	.70	.85	.59		7	9	9	10	5	12	8
Tuamotu (TUA)	.76	.83	.54	.77	.02	.46		10	12	8	7	15	10
Mangareva (MGR)	.91	.90	.86	.89	.78	.80	.66		13	15	10	13	11
Australs (AUS)	.84	.81	.62	.82	.29	.66	.37	.77		12	11	15	12
Rapa (RAP)	.90	.89	.82	.86	.79	.85	.79	.79	.67		11	17	13
Hawaii (HAW)	.89	.81	.85	.89	.80	.87	.79	.92	.81	.95		12	11
Easter (EAS)	.97	.95	.92	.95	.91	.90	.89	.86	.94	.90	.97		14
New Zealand (NZ)	.76	.76.	.76	.90	.76	.88	.76	.92	.79	.91	.91	1.00	

We can answer this question if we go back to the data on which the networks in figures 1 and 2 are based and apply the statistical method known as the quadratic assignment procedure. This is a nonparametric permutational method for determining whether there is a statistically significant relationship between two "similarity matrices." A similarity matrix is a square matrix whose entries show the degree of similarity between pairs of elements. In the present case the entries in one matrix would show the accessibility between pairs of islands while the entries in the other matrix would show their cultural, linguistic, or biological similarity. We will use the quadratic assignment procedure to test Irwin's hypothesis concerning the relation between accessibility and cultural similarity in Polynesia. Tests for the relation between accessibility and linguistic and biological similarity must await the collection of more complete data. The linguistic data consisting of shared cognates in Polynesian languages from Clark (1979) are limited to eight of the societies in Irwin's analysis, while the biological data from Pietrusewsky (1971) are limited to eight of these societies with Samoa and Tonga not distinguished. To use the quadratic assignment procedure the matrices must be of the same order.

Irwin's accessibility network is constructed from two preliminary matrices, one of which gives the geographical distance and the other the minimum angle of target size between islands in Polynesia. The entries in these matrices are percentages of greatest distance and greatest angle of target size. These two matrices are combined in a single mutual accessibility matrix by calculating each cell's geometric mean, that is, by multiplying the two corresponding values for each cell and taking the square root of the product. On the basis of this similarity matrix, Irwin constructs a network in which islands are joined to some of their more accessible neighbors as shown in figure 1. We have subtracted the entries in Irwin's (symmetric) matrix from 100 so that the lower the number the greater the accessibility between pairs of islands. The result is shown in the lower diagonal half of table 1.

Irwin defines cultural similarity in terms of Burrows's (1938) classic study in Polynesian ethnology. On the basis of a distributional analysis of cultural traits, including artifacts, aspects of social organization, and religious ideas, Burrows identified the four subgroupings shown in figure 2. From Burrows's tabulation of cultural traits in Polynesia we have constructed a matrix showing the number of traits shared by pairs of islands.[4] The maximum number of shared traits between any pair of islands is 18. We have subtracted this number from 20 so that the lower the number the greater the degree of cultural similarity. This (symmetric) matrix occupies the upper diagonal half of table 1.

We now have two similarity matrices that we wish to compare: one in the upper triangular half of table 1 showing the degree of cultural similarity between pairs of islands and the other in the lower triangular half of table 1 showing their mutual accessibility. Such matrix comparisons have been difficult in the past because standard statistical analyses require, as a critical assumption, that the observations be independent of one another. In the present case, we have $13 \times (13 - 1)/2 = 78$ observations derived from pairing the 13 island communities. These observations are clearly not inde-

4. In constructing this matrix, traits classified by Burrows as "slightly developed," "exceptional," "recent," "few examples," "rare," "localized," and "questionable" were counted as absent; traits classified as "present but not prevalent" were counted as present. "Primal gods" were counted if all four were found. Traits in Burrows's diagrams 2, 4, and part of 15 pertaining to barkcloth, the kava ceremony, and bonito hooks were omitted because of environmental limitations. Sail types in diagram 11 were omitted because it was not always possible to determine the aboriginal type. A trait was counted as present in the Northern Cooks if it was found on at least one of the three islands.