Michael P. Neeley
Geoffrey A. Clark
Department of Anthropology
Arizona State University
Tempe, AZ 85287-2402
USA

Michael P. Neeley and Geoffrey A. Clark

Measuring Long-Term Change in the Human Food Niche: A Levantine Example

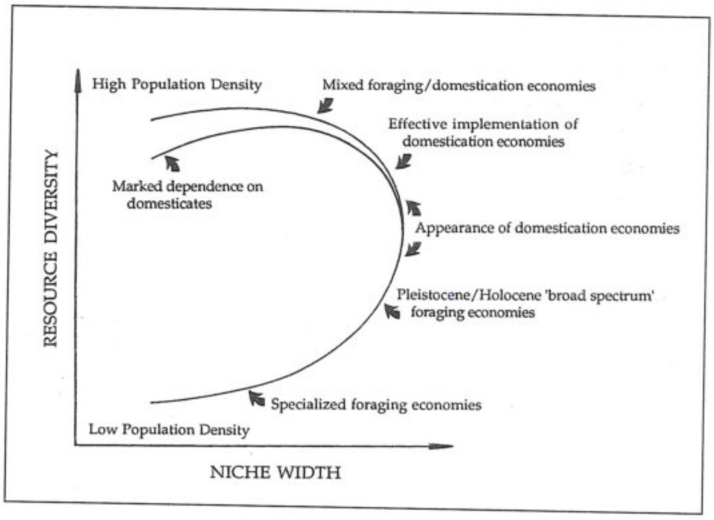
Introduction

Archaeologists have tended to accept Flannery's (1969) broad spectrum revolution (BSR) as a general phase in an evolutionary sequence of subsistence changes leading to the appearance of domestication economies. Previous partial tests of the Flannery model in both hemispheres have tended to support it, especially those aspects that predict increasing subsistence diversity over time, and increases in the relative intensity of food procurement (e.g. Earle 1980; Christenson 1980; Clark and Yi 1983; Clark 1987). Phillip Edwards has recently claimed, however, that the BSR is not documented in Levantine archaeofaunal data, and that its generality as a phase in the domestication process in that region can thus be called into question (Edwards 1989; cf. Binford 1968; 1983). He contends that diversified archaeofaunas have been present in the Levant since the Middle Palaeolithic, and that no changes in the direction of increasing diversity are discernible in the period immediately preceding the appearance of domestication economies there. Edwards' construal of pattern is juxtaposed here with the expectations of long-term, diachronic niche width models developed by Cohen (1977), Earle (1980) and Redding (1988). Although his conclusions partly mirror our own, we think there are problems with how Edwards measures diversity and with his construal of what constitutes the BSR.

The Broad Spectrum Revolution

In the classic formulation, the broad spectrum revolution is characterized by a series of changes in the subsistence economy beginning c. 20 kyr BP (the Epipalaeolithic in the Levant) that are manifest in a broadening of the human food niche (Flannery 1969). This increase in resource diversity was thought to continue until c. 8 kyr BP (the Neolithic) when reliance upon domestication economies is achieved in some areas of the Middle East. In the Levant, the broadening of the diet supposedly included a greater emphasis on smaller, more labor intensive, lower yield but more reliable food packages (e.g. fish, birds, shellfish) at the expense of the large and medium-sized, gregarious ungulates (e.g. deer, gazelle, equids, ovicaprines) that are the basis for Middle and Upper Palaeolithic subsistence. It is this pattern of increased diversity, attributed to a complex causal nexus involving population increase, environmental change, technological change and to changes in the organization of subsistence, that is believed to lead to the appearance of domestication economies (Flannery 1969: 79).

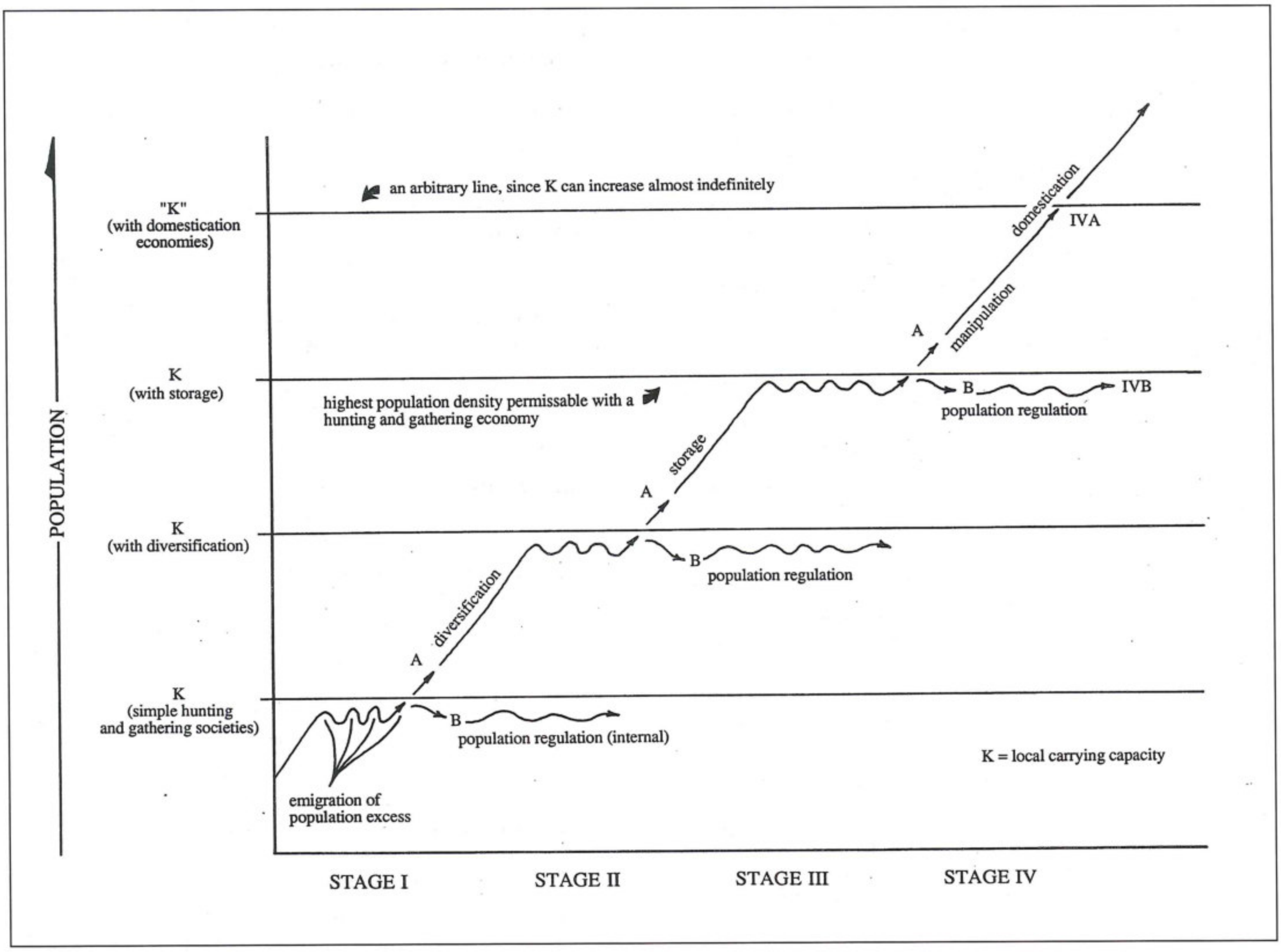
If simple diversity is plotted against niche width over time, the resulting curve is believed to have some generality, and to allow for the prediction of one variable, given a known value for the other (FIG. 1). The curve resembles a "backward C", with specialized foraging economies characterized by relatively low resource diversity occurring under conditions of low population density, followed by the BSR, where both resource diversity and niche width tend to increase, and to reach maximum values, the appearance of domestication economies and their effective implementation, marked by de-



1. Theoretical relationship between niche width and resource diversity under conditions of population growth, and with the least-cost selection assumption in effect (from Clark 1987: 296, modified from Christenson 1980: 37).

creases in diversity and niche width, and by increases in the rate of population growth. It is this sort of diversification-intensification trajectory (the "backward C"), ultimately powered by increases in population density and by regional population/resource imbalances, that has been presented in support of the BSR as a general evolutionary phase for regions outside the Middle East.

In a recent paper, Richard Redding (1988) has developed a universal generalization of the Flannery model, couched in terms of four evolutionary stages, each characterized by a prioritized hierarchy of tactics (FIG. 2). It is assumed that some local hunter-gatherer populations grew and stressed the resource base, thus forcing these groups to adopt certain tactics in order to cope with stress. Of interest to us is the role of diversification and the options associated with this subsistence tactic. In the Redding model, decisions must be made at various population and carrying capacity thresholds. These decisions are viewed in evolutionary terms and are expected to increase the overall fitness of the groups involved in the decision making process. Although the model is not intended to portray the change as unilineal, the ordering presented is believed to be the most likely general sequence of events or processes (Redding 1988: 75). Several aspects of his model are interesting for our purposes. One is the notion that the threshold of stress due to carrying capacity and population/resource imbalances does not have to be reached by all groups simultaneously. This implies that groups in relative proximity to each other might be operating on different levels in terms of the tactics or strategies employed. For our purposes it would not be unusual to see some variability in the regional data set that might be attributable to variable subsistence practices. Redding also indicates that diversity should be greatest prior to the advent of storage technology (1988: 85). This suggests that we might observe a



2. Redding's Model: Changes in local carrying capacity under conditions of population growth and with the adoption of emigration (Stage I), diversification (Stage II), storage (Stage III) and manipulation-domestication (Stage IV) strategies (after Redding 1988: 76, 79).

decrease in the overall diversity of site assemblages prior to the appearance of domestication economies as a result of the implementation of storage technologies.

Edwards' Results Summarized

After examining 72 Levantine archaeofaunal assemblages distributed across eight analytical units ranging in time from the Lower Palaeolithic to the Pre-Pottery Neolithic, Edwards suggested that, by the Middle Palaeolithic, a wide range of animals were being exploited for dietary purposes throughout western Asia, and that there was no evidence to support a broadening of the diet immediately prior to the appearance of domestication economies (1989). He concluded that the BSR, which predicts an increase in diversity beginning around 20 kyr BP, is inappropriate as a general evolutionary phase in the Levant.

Estimating Population Growth

One of the basic tenets of BSR-based models is that increases in population density over time are believed to drive the need to diversify the diet. Rather than simply reporting the number of site levels per culture-stratigraphic unit, it is clearly more appropriate to relate these numbers to a standardized measure of time. Scaling site numbers to unit time allows for comparability across culture-stratigraphic units of vastly different durations.

TABLE 1 gives the incidence of Levantine sites per millennium according to the seven analytical units most commonly used in the area. Data are derived from a variety of sources, including five regional surveys. It is apparent that the general expectation of population growth over time is met. After millennia of low values for the Middle, Upper and Epipalaeolithic, there is almost a three-fold increase when the Epipalaeolithic is compared with the Neolithic. Chalcolithic values nearly double again, and there is a substantial, although incremental, increase during the Bronze Age. Finally, in the Iron Age, scaled site numbers almost triple. While these trends are robust and are generally replicated within individual surveys, they are also influenced by the variable quality of the survey data upon which they are based.

Table 1. Estimate of population growth over time.[1]

Culture-Stratigraphic Unit	*# of sites*	*Temporal Duration*	*# of sites per millenium*
Middle Palaeolithic	347	65,000	5.33
Upper Palaeolithic	151	17,000	8.88
Epipalaeolithic	79	10,000	7.90
Neolithic	88	4,000	22.00
Chalcolithic	37	1,000	37.00
Bronze Age	102	1,800	56.66
Iron Age	114	700	162.85

[1] The data for this table represents results from 5 surveys in the Levant. They are: 1) Wādī al-Ḥasa (Clark *et al.* 1988a; MacDonald 1988a; 1988b); 2) the Southern Ghawr and Northeast ʻArabah (MacDonald *et al.* 1988; Neeley 1989); 3) an-Naqab and Sinai (Marks 1977); 4) the Ḥisma region (Henry *et al.* 1983); and 5) the Azraq Basin (Garrard *et al.* 1988a).

The Components of Diversity

The concept of diversity, as developed and employed in ecology, has often been misapplied in archaeological research. As a general notion, diversity connotes the amount of variability present in a sample or population, but such a definition is inappropriately vague when trying to measure diversity quantitatively. In a recent volume devoted to archaeological diversity questions (Leonard and Jones 1989), the component parts of diversity are identified as richness, evenness and heterogeneity (Bobrowsky and Ball 1989: 5). *Richness* is the number of taxa in a given sample or collection. Since it can be shown statistically that richness is a function of sample size, the unqualified use of the simple number of taxa present in a collection might be an inaccurate measure of richness. To assess richness with some degree of reliability, the effects of sample size must be taken into account. *Evenness* refers to the proportional distribution of taxa in the sample. It determines whether or not all of the taxa are represented more or less equally in a sample or collection, or whether a sample is dominated by a few very abundant taxa. Evenness measures are also affected by sample size differences (Bobrowsky and Ball 1989: 7). *Heterogeneity* attempts to measure the relationship between richness and evenness, and to express it as a single index. Heterogeneity measures are very popular with archaeologists, but they suffer from the drawback that we typically do not know which aspect of diversity is most heavily influencing the index. Given such problems with heterogeneity measures, any assessment of the Levantine archaeofaunal record should probably utilize separate measures of richness and evenness. While Edwards does not use a heterogeneity index, he measured only evenness (1989: 236, 237). To ignore richness, however, could result in an inadequate assessment of subsistence change in light of expectations derived from BSR-based models.

Kintigh's Simulation Approach

Having noted some of the problems associated with diversity indices, we sought to examine the richness component of Levantine archaeofaunas using a simulation approach developed by Keith Kintigh (1984; 1989). Kintigh has published simulation algorithms for both richness and evenness (1989) but McCartney and Glass (1990) have recently argued that the evenness measure he uses is in fact a heterogeneity statistic. His "evenness" statistic is a standardized measure which allows general comparability between cases. We used it in conjunction with the richness statistic to identify cases of interest given the potential interpretive problems summarized above. A strength of the simulation approach is that values for expected richness and evenness are generated for given sample sizes, and are accompanied in each case by confidence intervals. Thus the sample size problem is avoided at the individual assemblage level.

Levantine Archaeofaunal Data

The temporal span of both studies is approximately 100,000 years, but we divided ours into eight culture-stratigraphic analytical units, including three post-Neolithic periods (TABLE 2). The choice of these analytical units is partly a matter of convention, but they were also chosen on the assumption that, in order to detect possible changes in diversity associated with the BSR, bracketing periods of sufficient duration must be examined. Sixty-three assemblages are analyzed, compared with 72 (29) in Edwards' study (1989: 228, 229) (TABLE 2). Since most reports present information on all species recovered, regardless of their economic potential, we screened the data in order to isolate probable economic species. Only three publications did this consistently (Noy *et al.* 1980; Payne 1983; Saxon 1974). Building on these and other assessments of economic status, we decided to eliminate all rodents, insectivores, raptors, reptiles (except tortoises) and mollusca — the last because of inconsistent reporting and because the common ornamental use of shell, and absence of shell middens, suggested that they were not major dietary components (Edwards 1989: 231). This left 59 species of mammals, birds and fish as potential food items (TABLE 3).

Table 2. Faunal assemblages used for this study.

Middle Palaeolithic	
Douara Cave	Payne 1983
Far'ah II	Gilead and Grigson 1984
Qafzeh 11	Bouchud 1974
Qafzeh 15	Bouchud 1974
Qafzeh 22	Bouchud 1974
Wadi Hasa 621	Clark *et al.* 1988b
Tabun D	Bar-Yosef 1989
Bezez B	Garrard 1983
C-Spring	Clutton-Brock 1970
Upper Palaeolithic	
Kebara D	Saxon 1974
Kebara E	Saxon 1974
Wadi Hasa 618	Clark *et al.* 1988b
Qafzeh 9	Bouchud 1974
Jilat 9	Garrard *et al.* 1988b
Azraq 17	Garrard *et al.* 1988b
El Wad D	Bar-Yosef 1989
Kebaran	
Ein Gev I	Davis 1974
Wadi Hammeh 26	Edwards *et al.* 1988
Uweinid 18	Garrard *et al.* 1988b
Wadi Hasa 784x	Clark *et al.* 1988b
Jilat 6	Garrard *et al.* 1988b
Kebara C	Saxon 1974
Nahal Hadera V	Saxon *et al.* 1978
Hefsibah	Saxon *et al.* 1978
Ṭawr Ḥimār (Tor Hamar)	Henry and Garrard 1988
Iraq e Zigan	Heller 1978
Natufian	
Bayḍa (Beidha)	Hecker 1989
Wadi Hammeh 27	Edwards *et al.* 1988
Hayonim Terrace	Henry *et al.* 1981
Wadi Hasa 1065	Clark *et al.* 1988b
Kebara B	Saxon 1974
Wādī Judayid	Henry and Turnbull 1985
Rosh Horesha	Butler *et al.* 1977
Jilat 8	Garrard *et al.* 1988b
Jilat 10	Garrard *et al.* 1988b
Azraq 18	Garrard *et al.* 1988b
Jilat 6	Garrard *et al.* 1988b
Neolithic	
Jericho PPNA	Clutton-Brock 1979
Gilgal	Noy *et al.* 1980
Abū Sālim	Butler *et al.* 1977
Jericho PPNB	Clutton-Brock 1979
Bayḍa	Hecker 1982
'Ayn Ghazāl PPNB	Köhler-Rollefson *et al.* 1988
Wadi Tbeik	Tchernov and Bar-Yosef 1982
'Ayn Ghazāl PPNC	Köhler-Rollefson *et al.* 1988
'Ayn Ghazāl Yarmoukian	Köhler-Rollefson *et al.* 1988
Ujrat	Dayan *et al.* 1986
Jilat 7	Garrard *et al.* 1988b
Azraq 31	Garrard *et al.* 1988b
Jericho PN	Clutton-Brock 1979
Chalcolithic	
Jabal Jill	Henry and Turnbull 1985
Shiqmim	Grigson 1987
Ṣabī Abyaḍ	Akkermans 1987
Bronze Age	
Jericho EB	Clutton-Brock 1979
En Shadud	Horowitz 1985
Arad EB I	Lernau 1978
Arad EB II	Lernau 1978
Jericho MB	Clutton-Brock 1979
Tel Michel MB	Hellwing and Feig 1989
Tel Michel LB	Hellwing and Feig 1989
Iron Age	
Jericho Iron	Clutton-Brock 1979
Tel Michel Iron	Hellwing and Feig 1989
Tel Michel Persian	Hellwing and Feig 1989

Table 3. Levantine archaeofaunal genera, species.

1. *Equus equus, asinus* (horse, hemione, zebra, ass)
2. *Sus scrofa* (boar, domestic pig)
3. *Dama mesopotamica* (fallow deer)
4. *Capreolus Capreolus* (roe deer)
5. *Cervus elaphus* (red deer)
6. *Bos primigenius* (auroch)
7. *Bos taurus* (domestic cattle)
8. *Alcelaphus bucelaphus* (hartebeest)
9. *Gazella gazella* (gazelle)
10. *Capra ibex* (ibex)
11. *Ovis cf. aries* (sheep)
12. *Capra/Ovis*
13. *Camelus cf. dromedarius* (camel)
14. *Dicerorhinus merki, hemitoechus* (rhino)
15. *Hippopotamus amphibius* (hippo)
16. Large ungulate
17. Small ungulate
18. *Lepus europaeus* (hare)
19. *Vulpes vulpes* (fox)
20. *Erinaceus europaeus* (hedgehog)
21. *Hemiechinus* (long eared hedgehog)
22. *Felis sp.* (cat)
23. *Canis lupus* (wolf)
24. *Panthera pardus, leo* (leopard, lion)
25. *Lynx lynx* (lynx)
26. *Martes martes* (marten)
27. *Meles taxus* (badger)
28. *Hyrax hyrax* (hyrax)
29. *Hystrix* (porcupine)
30. *Testudo* (tortoise)
31. *Clemmys* (tortoise)
32. *Teleostei* (boney fish)
33. *Sciurus* (squirrel)
34. *Struthio* (ostrich shell)
35. *Otididae* (shell)
36. *Potamon* (crab)
37. *Aves*
38. *Anas* (duck)
39. *Anser* (goose)
40. *Alectoris* (partridge)
41. *Rallus* (water bird)
42. *Phasianidae* (pheasant)
43. *Pteroclidae* (sand grouse)
44. *Fulica* (coot)
45. *Ciconia* (stork)
46. *Columba* (pigeon)
47. *Syrrhaptes* (sand grouse)
48. *Gallus* (wild chicken)
49. *Cygnus* (swan)
50. *Larus* (gull)
51. *Streptopelia* (dove)
52. *Tadorna* (shellduck)
53. *Vanellus* (harpwing)
54. *Bucephala* (duck)
55. *Ammoperdix* (partridge)
56. *Porphyrio* (gallinule)
57. *Chlamytodis* (bustard)
58. *Coturnix* (quail)
59. *Clarias* (fish)

Dropped

Hyaena (stripped hyena)
Crocuta (spotted hyena)
Mustela mivalis (polecat)
Buteo (buzzard)
Bubo (owl)
Vormella (polecat)
Aquila (eagle)
Passeriformes (sm. birds)
Galerida (lark)
Corvus (crow)
Falconiformes (falcons)
Neophron (vulture)
Ketupa (brown fish owl)
Circus (harrier)

Species Diversity: Means and Frequencies

A preliminary examination of the richness and evenness statistics that ignores sample size differences indicates some interesting trends. The total number of economic species per analytical unit fluctuates between 22 and 27 from the Middle Palaeolithic through the Kebaran, and then rises sharply and attains a maximum during the Natufian and the Neolithic (TABLE 4). This peak is followed by an even steeper decline during the Chalcolithic, and by subsequent partial recovery and fluctuation in the post-Neolithic periods. Taken at face value, such a crude measure tends to support the BSR concept, but maximum diversity appears to occur in the late, rather than in the early Epipalaeolithic. The decline in richness associated with the effective implementation of domestication economies during the post-Neolithic eras also agrees with vectored subsistence change under conditions of increased population density predicted by BSR-based models (e.g. Christenson 1980; Clark 1987; cf. FIG. 1).

Inspection of maximum richness values indicates a trend toward increasing richness through time, with a peak during the Natufian and the Neolithic, followed by a rather sharp decline (TABLE 4). While again supportive of the BSR concept, this measure represents only the single "most diverse" faunal assemblage from each time period. A better indicator of general time trends is mean species richness, which peaks once again in the Natufian/Neolithic and is, again, followed by a sharp decline. The mean richness values are probably affected to some extent by sample size differences.

The summary statistics for evenness tend to support

Table 4. Mean values and frequencies of species richness for Levantine archaeofaunas.

Period	*N*	*# of species*	*Maximum # of species*	*Mean Richness*
Middle Palaeolithic	9	26	14	8.55
Upper Palaeolithic	7	22	17	8.28
Kebaran	10	27	14	8.40
Natufian	11	35	20	10.72
Neolithic	13	43	17	11.15
Chalcolithic	3	15	12	8.66
Bronze Age	7	23	13	9.14
Iron Age	3	17	12	9.00

Edwards' conclusion that the highest mean evenness values coincide with the Middle Palaeolithic and then decline steadily through the Neolithic (TABLE 5). In the post-Neolithic periods, mean evenness increases slightly but never to the level reached in the Middle Palaeolithic. It was this sort of trend and statistic (mean values regardless of sample size) that Edwards used to support his claim that diversity was highest early on and not in the Epipalaeolithic, as the BSR model would suggest. Aside from the sample size problem, other factors need to be considered in his interpretation. Foremost is the assumption that higher evenness is equal to greater diversity. Since evenness is a monitor of the *proportional* distribution of species, a high evenness value might indicate a relatively equal proportion of species utilization while a lower evenness statistic might correspond to more selective species utilization or an increase in the number of species utilized. In the latter instance, "traditional" resources might be utilized in the same frequencies but because of added species, their proportional representation would decline. It is possible that the decline in mean evenness over time is in response to an increase in the number of species utilized (richness), a trend which is apparent from the mean richness values.

Species Diversity: Simulations Within Time Periods

Plots were generated for each of the eight analytical units using Kintigh's simulation program. The results of these simulations are summarized in FIGS. 3-10. The range of expected values for the samples are represented by the three lines, and the placement of individual assemblage scores in relation to them by solid rectangles. The center line is the mean expected value, and the lines that bracket it are the upper and lower 90% confidence intervals.

Middle Palaeolithic

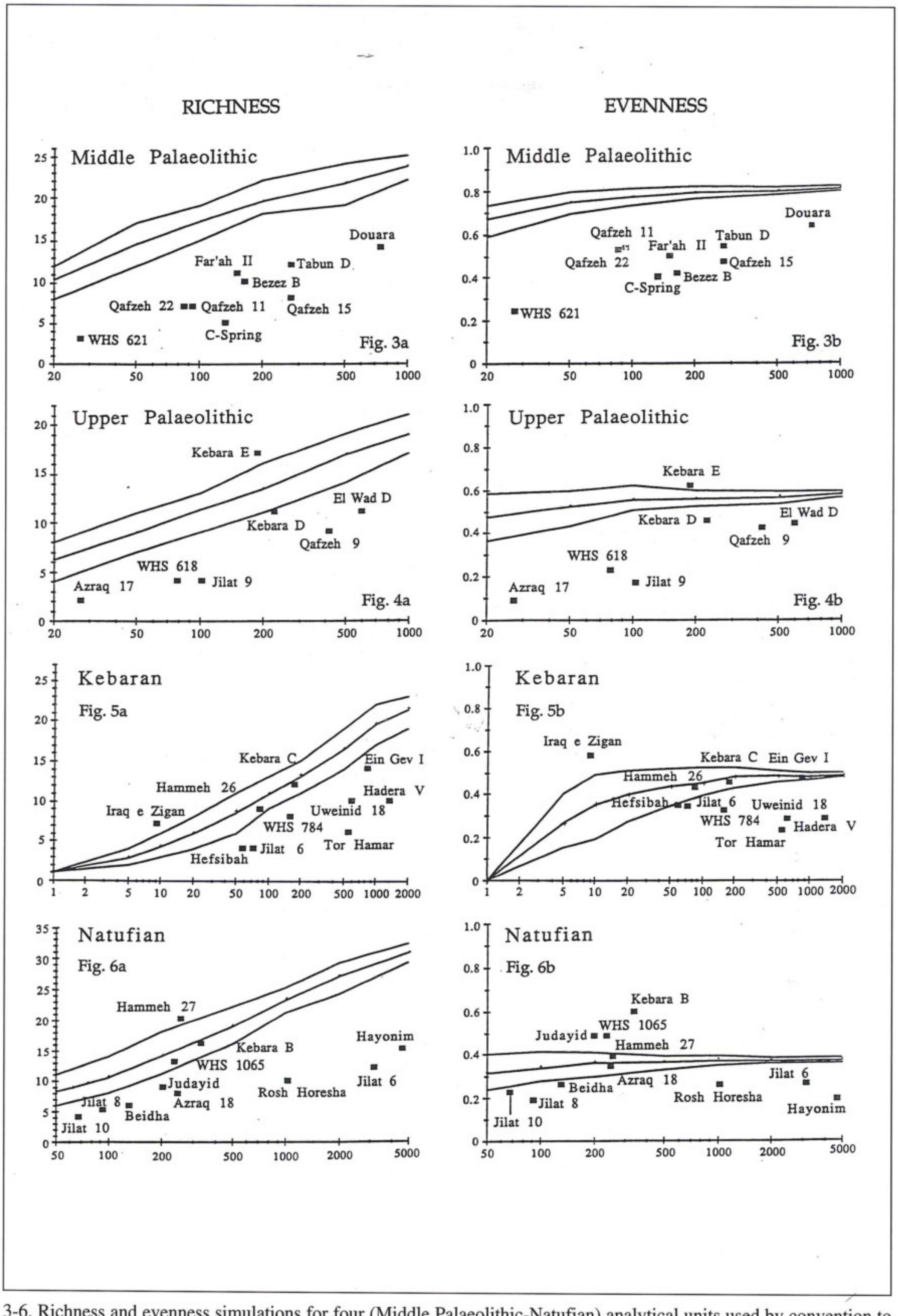
As might be expected, interpretation of the within-period simulations is not as straightforward as the mean and frequency data. This is due in part to the general tendency for all periods to exhibit levels of richness *beneath* the confidence interval. Exact fit within the bounds of the confidence interval is not expected, since the confidence intervals serve as a general model of the sample size effect to which the data are expected to conform. The Middle Palaeolithic pattern indicates that richness and evenness tend to be a result of the sample size effect (FIGS. 3a, 3b). This apparently generalized economic behavior might reflect a sort of "random" sample of species from the local environment. This is somewhat surprising since most Levantine Middle Palaeolithic samples come from rockshelter contexts that are thought to have more diverse faunas than open sites.

Upper Paleolithic

The Upper Paleolithic simulations indicate that most of the sites follow the linear sample size trend predicted by the simulation model (FIGS. 4a, 4b). However, one assemblage (Kebara E) is richer than expected, and another (Kebara D) falls just below the lower confidence interval. The remainder adhere to a pattern consistent with the sample size effect. While the richest Upper Palaeolithic assemblages are from Kebara, other rockshelter assemblages conform to expected trends, as do Upper Palaeolithic open sites.

Table 5. Summary statistics of species evenness for Levantine archaeofaunas.

Period	*N*	*Max.*	*Min.*	*Mean*	*Median*
Middle Palaeo.	9	.6305	.2391	.4736	.5000
Upper Palaeo	7	.6159	.0854	.3438	.4194
Kebaran	10	.5732	.2374	.3781	.3501
Natufian	11	.5884	.1859	.3312	.2586
Neolithic	13	.5216	.1262	.3167	.3074
Chalcolithic	3	.5951	.2191	.4337	.4871
Bronze Age	7	.5518	.2186	.3878	.3550
Iron Age	3	.5283	.1436	.2857	.1853



3-6. Richness and evenness simulations for four (Middle Palaeolithic-Natufian) analytical units used by convention to structure Levantine archaeological research.

Kebaran

In examining the richness simulation for the Kebaran, the tight, linear sample size effect noted for the Middle and Upper Palaeolithic is less apparent when the individual assemblage distribution is compared to the confidence interval (FIGS. 5a, 5b). A considerable amount of variability in the distribution of the assemblages suggests a difference in animal exploitation which is not apparent in the earlier periods.

Natufian

In some contrast to the Kebaran plots, the Natufian assemblages tend to conform to the expected sample size trend generated by the simulation (FIGS. 6a, 6b). Although all assemblages do not deviate from the sample size effect, the fact that some do indicates a continuation of behavioral activities that were largely absent prior to the early Epipalaeolithic.

Neolithic

The higher richness values continue into the Neolithic where three collections fall within or above the confidence intervals (FIGS. 7a, 7b). In general a roughly linear trend due to the sample size effect can be detected for most of the other samples, though many are of a similar size and tend to cluster in the center of the diagram. Perhaps most interesting is the appearance of a very large collection with a low richness value (Bayḍa/Beidha). This is the first indication of some sort of fairly clear-cut economic specialization. It is not surprising that this signature appears for the first time in the Neolithic, when the earliest, undisputed domestication economies occur. All are open air sites, which might signal a change in richness when compared with the pre-Neolithic samples. Many of the latter were recovered from rockshelters, which tend to have better-preserved faunas and which also serve as carnivore lairs and dens, and which are frequented by raptors.

Chalcolithic

Interpretation of the Chalcolithic simulation is difficult because the sample size is so small (3 sites) (FIGS. 8a, 8b). While the sharp drop in the number of species exploited, as compared to the Neolithic, indicates a significant difference in resource exploitation, there is a high likelihood that the richness and evenness simulations are compromised by the small sample size. As a result, the interpretation of very small samples should be set aside until more robust data sets can be obtained.

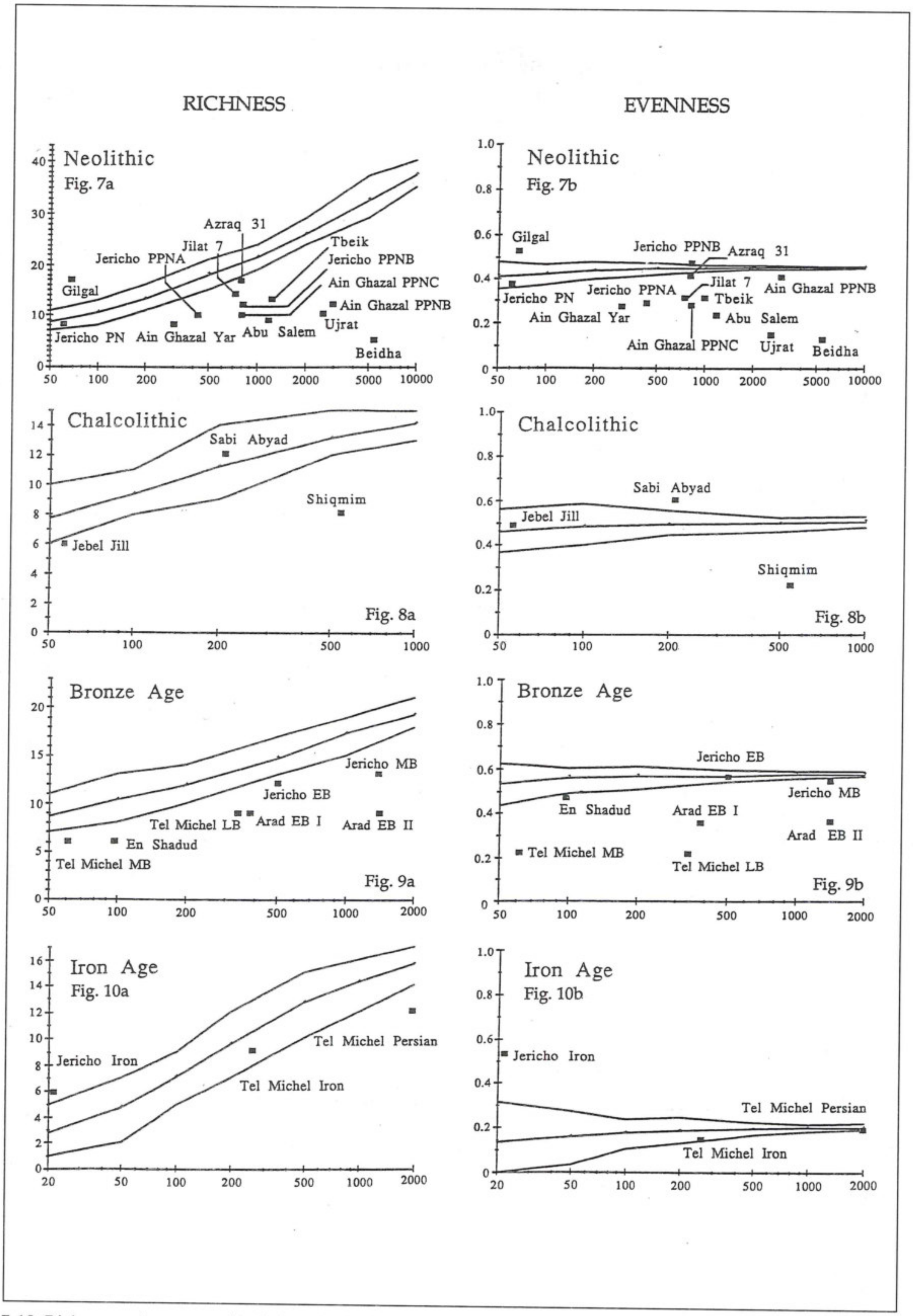
Bronze and Iron Ages

No Bronze Age sample falls within the range of expected values (FIGS. 9a, 9b). This suggests that the increased diversity characteristic of the Natufian and Neolithic has begun to decline in subsequent periods, probably because of the combined effects of intensive agropastoral economies, and increasingly widespread habitat destruction. Finally, the three Iron Age assemblages suffer from the same small sample size effect as the Chalcolithic assemblages and any attempt to interpret pattern in these would be misleading (FIGS. 10a, 10b).

Conclusions

In summary, the patterns noted in the within-period simulations are by no means conclusive, but the overall trend is at least suggestive of some support for the BSR. Because richness and evenness generally follow a sample size trend in all analytical units, exact replication of patterns expected under BSR-based models is not achieved. While the patterns might be affected by the variables selected (unlikely, in our view), or by the fact that some units are only represented by a few collections (see Chalcolithic and Iron Age) or by some defect in the simulation algorithm itself, we cannot partition potential sources of error except impressionistically. Taking the sample size effects into account, these Levantine archaeofaunas all do in fact appear to become more rather than less diverse through time. This directly contradicts Edwards' conclusions that they are relatively diverse throughout the entire sequence (1989: 240-242).

At present, our results and those of Edwards cannot be reconciled, and we are at something of a loss to explain why. We maintain that conclusions drawn from Edwards' study are problematic because of his use of an evenness measure, and the fact that he ignored richness, his failure to consider subsistence changes more recent than a relatively early phase of the Neolithic, his failure to distinguish between economic and non-economic faunas, and his failure to take sample size effects into account. His contention that Levantine archaeofaunas were diverse from start to finish, and that no vectored change in the direction of increasing diversity was apparent during the most likely BSR interval, the Epipalaeolithic, appears to us to be unfounded. While we cannot claim to have demonstrated the existence of the BSR in these data, we submit that the weight of evidence favors our position, and we categorically reject Edwards' claim that taxonomic diversity is unrelated to trends toward food production at the end of the Pleistocene. In our opinion, BSR-based models retain considerable explanatory potential, and have developed to the point where fairly explicit test implications can be generated from them, and then compared with regional data sets like this one. We would be loath to abandon them simply because of instances where pattern searches do not neatly coincide with expectations, especially in the absence of viable alternative explanations.



7-10. Richness and evenness simulations for four (Neolithic-Iron Age) analytical units used by convention to structure Levantine archaeological research.

Acknowledgements
This is "Wadi Hasa Paleolithic Project Contribution No. 13," supported by the National Science Foundation (Grant Nos. BNS-8405601, BNS-8921863, BNS-9013972), the National Geographic Society (Grant No. 2914-84), the Chase Bank of Arizona and the Research Vice-President's Office, Arizona State University (Grant No. 90-0729). The support of the Department of Antiquities, Hashemite Kingdom of Jordan, and the American Center for Oriental Research (Amman) is gratefully acknowledged.

References

Akkermans, P. M. M. G. 1987. A Late Neolithic and Early Halaf Village at Sabi Abyad, Northern Syria. *Paléorient* 13: 23-40.

Bar-Yosef, O. 1989. Upper Pleistocene Human Adaptations in Southwest Asia. In E. Trinkaus (ed.), *Corridors, Cul de Sacs and Coalescence: The Biocultural Foundations of Modern People.* Cambridge: Cambridge University Press.

Binford, L. R. 1968. Post-Pleistocene Adaptations. Pp. 313-341 in S. R. Binford and L. R. Binford (eds.), *New Perspectives in Archaeology.* Chicago: Aldine.

___ 1983. *In Pursuit of the Past.* New York: Thames and Hudson.

Bobrowsky, P. T. and Ball, B. F. 1989. The Theory and Mechanics of Ecological Diversity in Archaeology. Pp. 4-12 in R. D. Leonard and G. T. Jones (eds.), *Quantifying Diversity in Archaeology.* Cambridge: Cambridge University Press.

Bouchud, J. 1974. Etude préliminaire de la faune provenant de la grotte du Djebel Qafzeh, près de Nazareth, Israël. *Paléorient* 2: 87-102.

Butler, B. H., Tchernov, E., Hietala, H. and Davis, S. 1977. Faunal Exploitation During the Late Epipaleolithic in the Har Harif. Pp. 327-345 in A. E. Marks (ed.), *Prehistory and Paleoenvironments in the Central Negev, Israel*, II. Dallas: SMU Press.

Christenson, A. L. 1980. Change in the Human Food Niche in Response to Population Growth. Pp. 31-72 in T. K. Earle and A. L. Christenson (eds.), *Modeling Change in Prehistoric Subsistence Economies.* New York: Academic Press.

Clark, G. A. 1987. From the Mousterian to the Metal Ages: Long-Term Change in the Human Diet of Northern Spain. Pp. 293-316 in O. Soffer (ed.), *The Pleistocene Old World: Regional Perspectives.* New York: Plenum Publishing.

Clark, G. A. and Yi, S. 1983. Niche-Width Variation in Cantabrian Archaeofaunas: A Diachronic Study. Pp. 183-208 in J. Clutton-Brock and C. Grigson (eds.), *Animals and Archaeology:1. Hunters and their Prey.* Oxford: BAR Int. Ser. 163.

Clark, G. A., Majchrowicz, D. and Coinman, N. R. 1988a. A Typological and Technological Study of Upper Paleolithic Collections from the WHS with Observations on Adjacent time-stratigraphic Units. Pp. 87-127 in B. MacDonald (ed.), *The Wadi Hasa Archaeological Survey (1979-1983), West-Central Jordan.* Waterloo: Wilfrid Laurier University Press.

Clark, G. A., Lindly, J., Donaldson, M., Garrard, A., Coinman, N., Schuldenrein, J., Fish, S. and Olszewski, D. 1988b. Excavations at Middle, Upper and Epipaleolithic Sites in the Wadi Hasa, West-Central Jordan. Pp. 209-285 in A. N. Garrard and H. G. Gebel (eds.), *The Prehistory of Jordan.* Oxford: BAR Int. Ser. 396.

Clutton-Brock, J. 1970. The Fossil Fauna from an Upper Pleistocene site in Jordan. *Journal of Zoology* 162: 19-29.

___ 1979. The Mammalian Remains From the Jericho Tell. *Proceedings of the Prehistoric Society* 45: 135-157.

Cohen, M. N. 1977. *The Food Crisis in Prehistory: Overpopulation and the Origins of Agriculture.* New Haven: Yale University Press.

Davis, S. 1974. Animal Remains from the Kebaran site of Ein Gev I, Jordan Valley, Israel. *Paléorient* 2: 453-462.

Dayan, T., Tchernov, E. and Bar-Yosef, O. 1986. Animal Exploitation in Ujrat el-Meked, a Neolithic Site in Southern Sinai. *Paléorient* 12: 105-116.

Earle, T. K. 1980. A Model of Subsistence Change. Pp. 1-29 in T. K. Earle and A. L. Christenson (eds.), *Modeling Change in Prehistoric Subsistence Economies.* New York: Academic Press.

Edwards, P. C. 1989. Revising the Broad Spectrum Revolution: and its Role in the Origins of Southwest Asian Food Production. *Antiquity* 63: 225-246.

Edwards, P. C., Bourke, S. J., Colledge, S. M., Head, J. and Macumber, P. G. 1988. Late Pleistocene Prehistory in Wadi al-Hammeh, Jordan Valley. Pp. 525-565 in A. N. Garrard and H. G. Gebel (eds.), *The Prehistory of Jordan.* Oxford: BAR Int. Ser. 396.

Flannery, K. V. 1969. Origins and Ecological Effects of Early Domestication in Iran and the Near East. Pp. 73-100 in P. J. Ucko and G. W. Dimbleby (eds.), *The Domestication and Exploitation of Plants and Animals.* Chicago: Aldine.

Garrard, A. N. 1983. The Paleolithic Faunal Remains from Adlun and their Ecological Context. Pp. 397-409 in D. Roe (ed.), *Adlun in the Stone Age: The Excavations of D.A.E. Garrod in the Lebanon, 1958-1963.* Oxford: BAR Int. Ser. 159.

Garrard, A. N., Betts, A., Byrd, B., Colledge, S. and Hunt, C. 1988a. Summary of Paleoenvironmental and Prehistoric Investigations in the Azraq Basin. Pp.

311-337 in A. N. Garrard and H. G. Gebel (eds.), *The Prehistory of Jordan.* Oxford: BAR Int. Ser. 396.

Garrard, A. N., Colledge, S., Hunt, C. and Montague, R. 1988b. Environment and Subsistence during the Late Pleistocene and Early Holocene in the Azraq Basin. *Paléorient* 14: 40-49.

Gilead, I. and Grigson, C. 1984. Far'ah II: A Middle Paleolithic Open-Air Site in the northern Negev, Israel. *Proceedings of the Prehistoric Society* 50: 71-97.

Grigson, C. 1987. Shiqmim: Pastoralism and Other Aspects of Animal Management in the Chalcolithic of the Northern Negev. Pp. 219-241 in T. E. Levy (ed.), *Shiqmim I.* Oxford: BAR Int. Ser. 356.

Hecker, H. M. 1982. Domestication Revisited: Its Implications for Faunal Analysis. *Journal of Field Archaeology* 9: 217-236.

___ 1989. Beidha Natufian: Faunal Report. Pp. 97-101 in B. F. Byrd, *The Natufian Encampment at Beidha.* Jutland Archaeological Society Publications XXIII. Aarhus: Aarhus University Press.

Heller, J. 1978. The Faunal Remains of Iraq e Zigan, a Late Pleistocene site on Mt. Carmel. *Israel Journal of Zoology* 27: 11-19.

Hellwing, S. and Feig, N. 1989. Animal Bones. Pp. 236-247 in Z. Herzog, G. Raap, Jr. and O. Negbi (eds.), *Excavations at Tel Michel, Israel.* Minneapolis and Tel Aviv: The University of Minnesota Press and The Sonia and Marco Nadler Institute of Archaeology.

Henry, D. O. and Garrard, A. N. 1988. Tor Hamar: An Epipaleolithic Rockshelter in Southern Jordan. *PEQ* 120: 1-25.

Henry, D. O., Leroi-Gourhan, A. and Davis, S. 1981. The Excavation of Hayonim Terrace: An Examination of Terminal Pleistocene Climatic and Adaptive Change. *Journal of Archaeological Science* 8: 33-58.

Henry, D. O., Hassan, F. A., Cooper Henry, K. and Jones, M. 1983. An Investigation of the Prehistory of Southern Jordan. *PEQ* 83: 1-24.

Henry, D. O. and Turnbull, P. F. 1985. Archaeological and Faunal Evidence from Natufian and Timnian Sites in Southern Jordan. *BASOR* 257: 45-64.

Horowitz, L. K. 1985. The En Shadud Faunal Remains. Pp. 168-177 in E. Braun (ed.), *En Shadud: Salvage Excavations at a Farming Community in the Jezreel Valley, Israel.* Oxford: BAR Int. Ser. 249.

Kintigh, K. W. 1984. Measuring Archaeological Diversity by Comparison with Simulated Assemblages. *AA* 49: 44-54.

___ 1989. Sample Size, Significance, and Measures of Diversity. Pp. 25-36 in R. D. Leonard and G. T. Jones (eds.), *Quantifying Diversity in Archaeology.* Cambridge: Cambridge University Press.

Köhler-Rollefson, I., Gillespie, W. and Metzger, M. 1988. The Fauna from Neolithic Ain Ghazal. Pp. 423-430 in A. N. Garrard and H. G. Gebel (eds.), *The Prehistory of Jordan.* Oxford: BAR Int. Ser. 396.

Leonard, R. D. and Jones, G. T. 1989. *Quantifying Diversity in Archaeology.* Cambridge: Cambridge University Press.

Lernau, H. 1978. Faunal Remains, Strata III-I. Pp. 83-113 in R. Amiran (ed.), *Early Arad.* Jerusalem: Israel Exploration Society.

MacDonald, B. 1988a. The Early to Late Bronze Periods. Pp. 155-170 in B. MacDonald (ed.), *The Wadi el Hasa Archaeological Survey 1979-1983, West-Central Jordan.* Waterloo: Wilfrid Laurier University Press.

___ 1988b. The Iron Age Periods. Pp. 171-189 in B. MacDonald (ed.), *The Wadi el Hasa Archaeological Survey 1979-1983, West-Central Jordan.* Waterloo: Wilfrid Laurier University Press.

MacDonald, B., Clark, G. A. and Neeley, M. 1988. Southern Ghors and Northeast 'Araba Archaeological Survey 1985 and 1986, Jordan: A Preliminary Report. *BASOR* 72: 23-45.

Marks, A. E. 1977. Introduction: A Preliminary Overview of Central Negev Prehistory. Pp. 3-34 in A. E. Marks (ed.), *Prehistory and Paleoenvironments in the Central Negev, Israel,* II. Dallas: SMU Press.

McCartney, P. H. and Glass, M. F. 1990. Simulation Models and the Interpretation of Archaeological Diversity. *AA* 55: 521-536.

Neeley, M. P. 1989. *The Late Pleistocene and Early Holocene Prehistory in the Southern Ghor and Northeast Araba, Jordan.* Master's Thesis, Department of Anthropology, Arizona State University, Tempe.

Noy, T., Schuldenrein, J. and Tchernov, E. 1980. Gilgal, a Pre-Pottery Neolithic A Site in the Lower Jordan Valley. *IEJ* 30: 63-82.

Payne, S. 1983. The Animal Bones from the 1974 Excavations at Douara Cave. Pp. 1-108 in K. Hanihara and T. Akazawa (eds.), *Paleolithic Site of the Douara Cave and Paleogeography of Palmyra Basin in Syria,* Part III. Tokyo: University of Tokyo Press.

Redding, R. 1988. A General Explanation of Subsistence Change: From Hunting and Gathering to Food Production. *Journal of Anthropological Archaeology* 7: 56-97.

Saxon, E. C. 1974. The Mobile Herding Economy of Mt. Carmel: An Economic Analysis of the Faunal Remains. *Journal of Archaeological Science* 1: 27-45.

Saxon, E. C., Martin, G. and Bar-Yosef, O. 1978. Nahal Hadera V: An Open-Air Site on the Israeli Coast. *Paléorient* 4: 253-266.

Tchernov, E. and Bar-Yosef, O. 1982. Animal Exploitation in the Pre-Pottery Neolithic B Period at Wadi Tbeik. *Paléorient* 8: 17-37.