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Some Further Remarks on Catchments, Nonproducers, and Tribute Flow in the Valley of Mexico

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In his comment on my recent study of Formative period sites in the Valley of Mexico, Hirth questions the model I presented and argues that some of the interpretations this model yielded are implausible. Unfortunately, a number of his criticisms seem to be based on serious misunderstandings of my original position. Whether these misunderstandings stem from a lack of clarity on my part or a misreading on his, I cannot say. But in either case, this confusion must be resolved before the substantive issues he raises can be dealt with.

Contrary to what Hirth implies, nowhere did I state and never have I believed that all Formative period subsistence activities were limited to a zone within 2 km of each site. What I did assume was that the bulk of *agricultural* activity took place in the immediate vicinity of each settlement (Steponaitis 1981:334-335). This assumption was based on ethnographic analogy and common sense. Indeed, the very same assumption has been made by virtually every Mesoamerican archeologist who has written about Formative village subsistence (e.g., Flannery 1976; Rossman 1976; Brumfiel 1976). In making this assumption, I did not intend to deny that Formative villagers went farther afield to hunt, fish, collect wild plants, and gather forest and mineral resources. Such activities are well-documented archeologically and, as Hirth points out, sometimes involved the establishment of camps far from the home village.

I agree that in applying the model to the Valley of Mexico, it would have been desirable to measure the productivity of a settlement's *entire* catchment, including outlying camps and taking into account all the floral and faunal resources exploited by a village's inhabitants. Yet doing this archeologically was clearly impossible. Most camps were probably so small and ephemeral that they would have escaped detection given the survey methods with which

the data were collected (Sanders et al. 1979:15-16). Moreover, even if such camps had been identified in the field, there would be no way of knowing which camps pertained to which villages. Thus, the only practical alternative was to assume that the bulk of subsistence came from agriculture, and that the bulk of agricultural activity was carried on within a certain radius of each settlement.¹ To put it another way, even if one acknowledged that agriculture was not the only source of food, it still seemed reasonable to suppose that agriculture was the most important source of food, and hence that agricultural productivity would be a major variable affecting the settlement's population of producers. Like it or not, this was the only way I could proceed.

The real issue, therefore, is not whether Formative villagers were absolutely confined to a restricted zone around each settlement, but whether an estimate of productivity based on such a restricted zone adequately approximates the relative productivity of the total catchment, whatever its true extent may have been. Fortunately, the bridging assumptions I made do not have to be accepted on faith, because they have certain implications that can be tested using the archeological record. As I explained at great length originally (Steponaitis 1981:325-332), if the premises of the model and the bridging assumptions hold true, then one would expect to find a linear relationship between site size and my index of catchment productivity. Furthermore, the linear relationship for villages should be such that zero productivity would imply zero size (in other words, the line defining this relationship should pass near the origin of the axes). Just such a relationship was found in all three Formative periods I considered (Table 1; see also Steponaitis 1981:340-358). Although some have alleged that this relationship is a spurious outcome of the way I defined catchment boundaries (Finsten et al. 1983), it can be demonstrated mathematically that such allegations have no basis in fact (Steponaitis 1983). Clearly, the size of Formative villages *can* be predicted from my index of catchment productivity, and until Hirth comes up with a better explanation for this empirical pattern, it would seem unwarranted to dismiss my model or its bridging assumptions as being too unrealistic.

Another misconception is evident in Hirth's statement that my analysis depended on the assumption that "villages were maximizing the total productivity of their catchment areas." This assertion is simply not true. My catchment

productivity index measured the amount of arable land within a fixed radius of each site. In order for such an index to be valid as a *relative* estimate of productivity (which is all that the model required), it was necessary to assume only the following: (1) that agriculturalists would walk only a certain maximum distance to reach their fields; (2) that this maximum distance was approximately the same for all sites of a given period; (3) that the average fertility of the arable land within each site's catchment was approximately the same; and (4) that within a given period all settlements farmed their catchments *at the same level of intensity*. Logically, there was absolutely no need to assume that this level of intensity represented, or even came close to, the maximum possible output given the technology of the time.

Be that as it may, Hirth then proceeds to calculate estimates of absolute carrying capacity for 1.5 and 2 km catchments, and argues that all villages and most centers could have supported themselves by intensively farming the land within these limits. This finding leads him to conclude that villages were probably "under-exploiting the available resources" and that centers need not have been supported by tribute drawn from the surrounding populations.

Given that I never assumed maximization to begin with, I would not be the slightest bit surprised to find that Formative villagers were underutilizing the land they had available, and

do not see that this in any way vitiates the model.

Moreover, even if some centers *could* have supported themselves by fully exploiting the land within a 2 km radius, this does not mean that they necessarily did. Leaving aside the tremendous uncertainty in the yield, following, and consumption estimates on which Hirth's calculations are based, the real problem in interpreting his figures is that we have no way of knowing what the typical radius of agricultural land use was during the Formative. Simply by changing the assumed catchment radius (not to mention the assumed intensity of production), one can obtain widely varying estimates of absolute productivity with which virtually any conclusion can be supported. How can Hirth be sure, for example, that Formative farmers did not generally adhere to a 1-km radius? If they did, his estimates of "agricultural potential" are greatly overdrawn. Such problems are inherent in any attempt to calculate absolute productivity in a prehistoric situation, and this is precisely why I relied exclusively on relative estimates in the original study. Using a relative index obviated the need to guess the actual radius of Formative land use, because the estimates derived for 1, 1.5, and 2 km catchments produced virtually identical results; hence, varying the assumed radius within this range had no substantial effect on the outcome of my analysis (Steponaitis 1981:335-336).

Table 1. Parameters of regression lines, site size versus catchment productivity (1.5 km), for nucleated villages and local centers.

Period	Site type	N	Slope ^a	y-Intercept ^a	Strength of correlation ^b	
					r ²	r
Middle Formative	Nucleated villages	6	.051 (± .011)	- 3.5 (± 7.7)	.85 (.49, .96)	.92 (.70, .98)
Late Formative	Local centers	4	.069 (± .020)	14.7 (± 16.7)	.85 (.10, .99)	.92 (.32, .99)
Late Formative	Nucleated villages	15	.059 (± .013)	- 13.3 (± 10.8)	.61 (.34, .79)	.78 (.58, .89)
Terminal Formative	Local centers	6	.051 (± .013)	27.8 (± 8.9)	.80 (.36, .95)	.89 (.60, .98)
Terminal Formative	Nucleated villages	9	.044 (± .009)	2.3 (± 4.4)	.78 (.50, .92)	.88 (.70, .96)

Values are taken from Steponaitis (1981, Tables 4, 5, and 8).

^a The standard error for each estimate is given in parentheses.

^b The 80% confidence interval for each estimate is given in parentheses.

Although Hirth's alternative interpretations may seem just as plausible as mine when considered in the abstract, it is important to remember one crucial fact: the tribute-flow model I proposed had an intricate set of logical implications that were found to be true in the data! If, as Hirth suggests, village size was unrelated to catchment productivity, then how does he account for the high correlations that were consistently observed (Table 1)? If centers did not derive support from tribute, how does he explain the multitiered nature of the size-productivity relationship, with centers consistently higher on the scatter diagram than nucleated villages (Table 1; also see Steponaitis 1981; Figs. 8 and 11)? In light of these empirical patterns, all of which are logically entailed by my model but not by his, Hirth's objections do not seem very compelling.

One other criticism Hirth raises is that my analysis resulted in implausible estimates for the number of nonproducers living at local and regional centers. He points out that according to my calculations, nonproducers often comprised 40%-60% of the people inhabiting Late and Terminal Formative centers, and that these figures exceed the percentages of nonproducers estimated for the Middle Horizon city of Teotihuacan. In my view, such a comparison is misleading because it ignores the fact that centers were not isolated, self-sufficient communities but rather were connected to a much larger regional system from which they drew support. Thus, the most meaningful way to draw proportional comparisons is not in terms of how many nonproducers lived in particular settlements but rather in terms of how many nonproducers were present in the region as a whole. When viewed in this way, the Valley of Mexico data make a lot more sense.

Although the proportion of nonproducers in some Formative centers appears to have been relatively high, the centers themselves were relatively small; not one of them is estimated to have contained more than 10% of the study area's inhabitants (Table 2). Hence, the proportion of nonproducers in the region as a whole was not at all excessive. According to the estimates derived from my model, nonproducers made up only 16% of the study area's population during the Late and Terminal Formative (Table 2; see also Steponaitis 1981, Tables 7 and 10).

The city of Teotihuacan, on the other hand, with only a third of its inhabitants being nonproducers, contained about 60% of the Valley

of Mexico's total population during the Middle Horizon (Sanders et al. 1979:183-219). Thus, the nonproducers living in Teotihuacan *alone* comprised 20% of the regional population, and this figure is certainly an underestimate of the total proportion, because it does not include the nonproducers who were living elsewhere in the valley at the same time. In addition to Teotihuacan, the valley contained at least 10 "provincial centers," one of which (Azcapotzalco) may have been inhabited by as many as 20,000 people (ibid.: 108, 193). Such centers were marked by monumental public architecture and undoubtedly contained large numbers of nonproducers. Moreover, Sanders et al. (ibid.: 126-127) argue that a large fraction of the rural settlements in Zumpango were inhabited by nonagriculturalists engaged in limestone quarrying and plaster production. Taking these other sites into account, the total number of nonproducers in Middle Horizon times at least equaled and probably exceeded 25% of the valley's population.

Thus, the existing data, when viewed in a regional framework, do show that the relative number of nonproducers was much lower in Formative times than during the Middle Horizon, just as one would expect. That Teotihuacan contained proportionally fewer nonproducers than some Formative centers is simply a reflection of differences in the way people were arranged over the landscape, and should not be construed to mean that the Middle Horizon system contained fewer nonproducers than the Formative systems that preceded it.²

Additional confirmation of the model's plausibility can be gleaned by calculating the tribute rates that would have been necessary to support the estimated number of nonproducers in the Valley of Mexico, and by comparing these calculations to tribute rates recorded for ethnographically known societies at a similar level of complexity (i.e., complex chiefdoms and simple states). As outlined in my original paper (Steponaitis 1981:325-332), two rates may be important in this regard, corresponding to two levels in the hierarchical flow of tribute. The first-order rate (t_1) expresses the average proportion of each household's subsistence production that is given up to the political establishment as tribute; using the size-productivity scatter diagrams on which my analysis was based, this value can be calculated from the size of centers in relation to nucleated villages, and is logically equivalent to the pro-

Table 2. Percentages of regional population found in Late and Terminal Formative centers.

Site designation	Period	Total residential area		Area occupied by nonproducers	
		ha ^a	regional % ^b	ha ^a	regional % ^b
CH-5	Late Formative	110.5	10.2	74.1	6.8
IX-2	Late Formative	31.5	2.9	11.1	10.0
IX-6	Late Formative	55.2	5.1	30.6	2.8
TX-12	Late Formative	73.1	6.7	26.2	2.4
CH-6	Late Formative	73.1	6.7	28.1	2.6
Total			31.6		15.7
Mean			6.3		3.1
TX-17	Terminal Formative	100.3	6.3	55.6	3.5
CH-14	Terminal Formative	109.7	6.9	76.3	4.8
IX-4	Terminal Formative	31.5	2.0	23.3	1.5
TX-1	Terminal Formative	62.9	3.9	18.7	1.2
TX-30	Terminal Formative	42.5	2.7	21.0	1.3
TX-50	Terminal Formative	44.2	2.8	11.3	0.7
CH-9	Terminal Formative	63.8	4.0	30.9	1.9
CH-16	Terminal Formative	63.4	4.0	21.5	1.3
Total			32.4		16.2
Mean			4.0		2.0

^a These data are taken from Steponaitis (1981, Tables 6 and 9).

^b The total number of residentially occupied hectares in the study area was 1084.2 during the Late Formative and 1601.1 during the Terminal Formative (Steponaitis 1981, Tables 7 and 10). The regional percentages are computed with reference to these totals.

portion of nonproducers in the total population. The second-order rate (t_2) corresponds to the fraction of all tribute collected at a local center which gets passed up to the paramount regional center; this rate can be estimated from the size of the regional center in comparison to the local centers. The values derived for t_1 and t_2 from the Valley of Mexico settlement data are summarized in Table 3 (for a detailed explanation of how these estimates were calculated, see Steponaitis 1981:331-332, n. 2).

It can be seen that the first-order tribute rate necessary to account for the number of nonproducers at Late and Terminal Formative centers is only about 16%. As I pointed out in the original paper, this figure compares favorably with a first-order tribute rate of 10%, which can be estimated ethnographically for the Tswana, a complex chiefdom in southern Africa (Steponaitis 1981, n. 11).

The second-order tribute rates estimated from the Valley of Mexico data range from about 29% to 46%. Although no comparative information on tribute flow at this level exists

for the Tswana, some relevant data can be found for the 19th-century Baganda state in east Africa. Here, the revenues gathered from each district within the kingdom are said to have been distributed as follows:

Table 3. Estimated tribute rates for the Formative period.

Period	t_1	t_2
Late Formative	.159	.29-.46 ^a
Terminal Formative	.162	.43-.44 ^b

These figures are taken from Steponaitis (1981, Tables 7 and 10, n. 10 and 13).

^a Variations in this estimate are the result of different assumptions about how many local centers were under the hegemony of the regional center CH-5.

^b The lesser figure represents the estimate for the Chalco regional center (CH-14), the greater figure the estimate for the Texcoco regional center (TX-17).

The Chief of a district received a portion of the taxes for himself and for his sub-chiefs; *the king took half for himself*, while the Katikiro [prime minister], the Kumbugwe [another official in the King's court], the Queen, and the King's Mother also had their portions. [Roscoe 1911:245, emphasis added]

This passage clearly suggests that the second-order tribute rate in the Baganda kingdom was in excess of 50%, which again shows that the archeologically-derived estimates for the Formative period fall within a believable range.

I hasten to add that none of the archeological estimates based on my model should be taken too literally, since they are subject to distortion from many possible sources of error (Steponaitis 1981:324-325, 334-337, 346-347). However, just because these estimates do not fit with Hirth's preconceptions does not mean that they are necessarily wrong or ethnographically implausible.

Indeed, there is good evidence from elsewhere in Mesoamerica that Formative period communities sometimes grew to include substantial contingents of nonproducers (i.e., nonagriculturalists). Perhaps the best documented example is the Terminal Formative site called Ts73/79, which is located in the Tehuacan Valley and was studied extensively by Spencer (1979). Based on a detailed mapping of architectural remains and controlled surface collections, Spencer was able to delineate three distinct segments within the community (as summarized in Table 4). One segment, consist-

ing of 80-85 households, appears to have been inhabited by elite families, specialized administrators, and obsidian workers; another segment, comprising 50-53 households, represented families engaged principally in ceramic production; and the third segment, containing 65-100 households, was inhabited by agriculturalists. Thus, of the 200 or so households that made up this community, Spencer argues that 56%-67% were nonproducers. Even if one were to question his interpretation that the inhabitants of the second segment were full-time ceramic specialists, one would still be left with a nonproducing contingent of at least 36%. These percentages—based on housemound counts and detailed intrasite analysis of artifacts—are very close to the estimates I derived independently for Formative centers in the Valley of Mexico (see Hirth's Table 3), and belie Hirth's claim that my results are unsupported by comparative evidence from elsewhere in Mesoamerica.

In sum, I do not believe that any of Hirth's objections seriously damage the credibility of my original argument. This is not to say that the model is without weaknesses, for, like all models, it presents a deliberate simplification of what was in reality a rather complex situation. As Clarke (1972:2) put it:

Models are often partial representations, which simplify the complex observations by the selective elimination of detail incidental to the purpose of the model. The model may thus isolate the essential factors and interrela-

Table 4. Community segments at Ts73/79.

Community segment	Number of houses		Interpretation
	Count	%	
Residential 1	80-85	36-41	Elite families, specialized administrators, and obsidian workers
Residential 2	50-53	22-26	Specialized ceramic producers
Residential 3	65-100	33-42	Specialized farmers
Total	195-238	100	

The information in this table is based on the analysis and interpretations of Spencer (1979:42-53).

tionships which together account for the variability of interest in the observations. . . .

Constructing such partial representations often entails making ideal assumptions and ignoring certain sources of variability that are known to exist. In this sense, models may sacrifice a certain amount of realism, but at the same time they help us to ask questions of our data and provide insights into how the prehistoric systems we deal with may have operated. The ideal assumptions on which a model is based may never hold perfectly true in the real world, but to the extent that the ideal assumptions are approximated, one might reasonably expect the model's predictions to be approximated as well. This was the spirit in which my model was formulated and applied to the Valley of Mexico data, and, at least to me, the results seemed to justify the effort.

NOTES

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¹ It is important to note that the general mathematical model I presented contains no premises as to what form the catchment should take or what resources it should produce (Steponaitis 1981:325-332). All my postulates concerning catchment radius and agricultural productivity are context-specific bridging assumptions, designed to operationalize the model in the particular case at hand.

² Incidentally, Hirth's belief that obsidian specialists did not constitute a significant component of the nonproducers at Formative centers has little to support it. Not one of the Late or Terminal Formative centers in the study area has yet been excavated, and the surveys that located these sites were not designed to systematically record evidence of craft activities (Sanders et al. 1979:16). Thus a definitive statement on this matter should await further evidence.

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