
Causes of Toolkit Variation Among Hunter-Gatherers: A Test of Four Competing Hypotheses

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ABSTRACT. Variation in subsistence-related material culture is an important aspect of the archaeological and ethnographic records, but the factors that are responsible for it remain unclear. Here, we examine this issue by evaluating four factors that may affect the diversity and complexity of the food-getting tools employed by hunter-gatherer populations: 1) the nature of the food resources; 2) risk of resource failure; 3) residential mobility; and 4) population size. We apply step-wise multiple regression analysis to technological and ecological data for 20 hunter-gatherer populations from several regions of the world. The analyses support the hypothesis that risk of resource failure has a significant impact on toolkit diversity and complexity. The results do not support the hypothesis that the characteristics of the resources exploited for food influence toolkit structure, or that residential mobility affects toolkit diversity and complexity. They are also not in line with the hypothesis that population size has an impact on toolkit structure. While our analyses appear to strongly support the suggestion that resource failure risk is the primary influence on hunter-gatherer toolkit structure, we argue that it would be premature to discount the other factors at this stage, and outline the steps that we believe need to be taken next.

RÉSUMÉ. Malgré le fait qu'il s'agisse d'un aspect important de l'archéologie et de l'ethnologie, les facteurs responsables du changement de la culture matérielle relié à la subsistance sont encore mal connus. Nous examinons quatre facteurs qui pourraient affecter la diversité et la complexité de l'outillage de subsistance des chasseurs-cueilleurs: 1) la nature des ressources alimentaires exploitées;

2) l'éventualité de manquer de ressources; 3) la mobilité résidentielle et 4) la taille de la population. Nous utilisons la régression multiple pour analyser les données technologiques et de subsistance de 20 populations de chasseurs-cueilleurs de diverses régions du monde. Les résultats de nos analyses n'appuient pas l'hypothèse selon laquelle les caractéristiques des ressources exploitées influencent significativement la diversité et la complexité des outillages, pas plus celle soulignant l'impact d'un mode d'établissement de type « mobilité résidentielle » ou encore celle arguant pour l'important rôle de la taille de la population. Alors que nos données montrent surtout que la structure de la composition de l'outillage est plutôt influencée par le facteur du risque d'échec, nous suggérons cependant qu'il est encore prématuré de rejeter ces trois derniers facteurs et nous proposons des avenues de recherche additionnelles.

MANY SIGNIFICANT EVENTS IN PREHISTORY were accompanied by changes in hunting and gathering technology (Bar-Yosef 2002; Dillehay 1999; Meltzer 1995; Schick and Toth 2001), and differences in the number and intricacy of tools used to obtain food are also involved in several of the geographic contrasts that have been recorded among historically documented hunter-

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gatherer groups (Oswalt 1973, 1976). Yet there is no consensus among archaeologists and anthropologists regarding the factors that influenced the structure of hunter-gatherer toolkits prior to the widespread adoption of guns and other Western technologies (e.g., Binford 2001; Bleed 1986; Bousman 1993; Kuhn 2004; Kuhn and Stiner 2000; Osborn 1999; Oswalt 1976; Torrence 1983, 1989, 2000; Vierra 1995). With this in mind, the present study uses multiple regression analysis to compare several hypotheses that offer competing explanations for hunter-gatherer toolkit variation. The hypotheses focus on the nature of the resources exploited for food, risk of resource failure, residential mobility, and population size, respectively.

Classifying and Quantifying Toolkit Variation

Before outlining the hypotheses, it is necessary to define some terms. The foundations for systematic research on the factors that influence hunter-gatherer toolkit structure were laid by Oswalt (1973, 1976). His studies were limited to tools that are employed directly in the acquisition of food, which he termed “subsistants.” As indicated in Table 1, Oswalt recognized three main types of subsistant: instruments, weapons, and facilities. *Instruments* are “hand-manipulated subsistants that customarily are used to impinge on masses incapable of significant motion and relatively harmless to people” (Oswalt 1976: 64); a *weapon* is “a form that is handled when in use and is designed to kill or maim species capable of significant motion” (Oswalt 1976: 79); and a *facility* is “a form that controls the movement of a species or protects it to man’s advantage” (Oswalt 1976: 105). He drew a distinction between simple and complex subsistants.

A *simple subsistant* “retains the same physical appearance before, during, and after it is brought into play” (Oswalt 1973: 27), while a *complex subsistant* “always has more than one component and its parts change in their physical relationship to one another during use” (Oswalt 1973: 28). He classified facilities as either tended or untended.

In addition to developing a cross-culturally applicable typology of tools, Oswalt (1973, 1976) devised several measures of toolkit structure. The first is the total number of subsistants, which is an indicator of the size, or what Torrence (1983, 1989) and Shott (1986) called the “diversity,” of a toolkit. The second is the total number of “technounits.” Put simply, technounits are the “different kinds of parts in a finished artifact” (Oswalt 1976: 45). More formally, a technounit is an “integrated, physically distinct, and unique structural configuration that contributes to the form of a finished artifact” (Oswalt 1976: 38). The total number of technounits included in a toolkit is a measure of its “complexity” (Oswalt 1976; Torrence 1983, 1989). Oswalt’s third measure of toolkit structure is the average number of technounits per subsistant. Again, this is a measure of toolkit complexity (Oswalt 1976; Shott 1986; Torrence 1983, 1989).

Diet and Toolkit Variation

The hypothesis that the nature of the resources exploited for food influences hunter-gatherers’ decisions regarding the structure of their toolkits was initially proposed by Oswalt (1976). Based on an analysis of the toolkits and diets of 20 hunter-gatherer populations, Oswalt argued that there is a relationship between a population’s degree of reliance on mobile resources and the complexity of its toolkit. He suggested

TABLE 1. Examples of types of subsistant cited by Oswalt (1973).

Subsistant type	Example
Instrument	Andamanese fruit-picking hook (p. 74) Naron digging stick (p. 58) Yahgan mussel-removing stick (p. 98)
Simple weapon	Andamanese wood club (p. 74) Naron spear (p. 58) Yahgan dagger (p. 98)
Complex weapon	Andamanese bow (p. 74) Caribou Eskimo bird spear and throwing board (p. 128) Yahgan harpoon dart (p. 99)
Simple tended facility	Andamanese dip-net and poison (p. 74) Caribou Eskimo fish lure (p. 129) Yahgan goose snare line (p. 99)
Complex tended facility	Angmagsalik raven snowhouse trap (p. 141) Caribou Eskimo caribou frightener (p. 129) Caribou Eskimo caribou pitfall (p. 129)
Simple untended facility	Angmagsalik sea gull snare (p. 141) Naron baited bird snare (p. 58) Yahgan comorant gorge (p. 99)
Complex untended facility	Angmagsalik fox deadfall (p. 141) Naron small mammal spring-pole snare (p. 58) Pitapita pitfall (p. 85)

that the exploitation of resources that are mobile (e.g., caribou) is more difficult and therefore demands more complex tools than the exploitation of immobile resources (e.g., tubers). Thus, populations that rely on animals can be expected to have more complex toolkits than populations whose diets are plant dominated. Oswalt also argued that because aquatic animals are more mobile than terrestrial animals, populations that depend on aquatic animals are likely to have more complex toolkits than populations that rely on terrestrial animals. The latter point was also made by Osborn (1999), who argued that when considering hunter-gatherer toolkit structure it is important to recognise that the organizational demands of terrestrial hunting differ from those of fishing and

aquatic hunting. He reported the results of an analysis in which the diversity and complexity of 21 hunter-gatherer populations' toolkits were correlated first with the percentage contribution to their diets made by terrestrial animals, and then with the percentage contribution to their diets made by marine animals. Osborn found that, in general, the procurement of marine animals explained more of the variability in toolkit diversity and complexity than did terrestrial animal procurement. Aquatic food dependence explained 26% of simple weapon diversity, 40% of simple weapon complexity, 47% of complex weapon diversity, 42% of complex weapon complexity, 54% of total toolkit diversity, 49% of total toolkit complexity, and 22% of average technological complexity.

The only toolkit structure measure that correlated more strongly with terrestrial animal procurement than with the procurement of aquatic animals was simple instrument diversity.

Risk and Toolkit Variation

The notion that risk of resource failure influences hunter-gatherer toolkit structure has its roots in Torrence's (1983) study of the relationship between technology and time stress. She hypothesized that as time stress increased hunter-gatherers could be expected to produce more specialised tools and therefore more diverse and complex toolkits. Torrence tested the time stress hypothesis by measuring the statistical association between toolkit structure and latitude in a sample of 20 hunter-gatherer populations. Torrence obtained technological data for these populations from Oswalt (1976). She employed latitude as a proxy for time stress on the grounds that "all other things being equal (e.g., altitude, rainfall) the length of the growing season for plants decreases on a global scale with increasing latitude" (Torrence 1983: 14). The significance of this, according to Torrence, is that as latitude increases the number of edible plants available for hunter-gatherers decreases and therefore they have to depend more heavily on animal resources, which, as noted above, are more taxing as far as search and pursuit time are concerned. Torrence's analyses strongly supported the time stress hypothesis. She found that toolkit diversity and complexity were positively and significantly correlated with latitude among the 20 populations in her sample.

Subsequently, Torrence (1989; 2000) abandoned the time stress hypothesis in favor of one based on risk. She defined the latter as the effects of stochastic

variation in the outcome associated with a behavior, and suggested that it is "made up both of the probability of not meeting dietary requirements and the costs of such a failure" (Torrence 2000: 77). She explained that she had come to believe that the necessity for increasing speed of capture and for budgeting limited time are merely the proximate causes of the variation in toolkit structure, and that the ultimate causes of the variation are the timing and severity of risk. Torrence went on to argue that the use of more specialised and therefore more elaborate tools reduces the risk of resource failure. Thus, populations that experience high resource failure risk will produce toolkits that are diverse and complex, whereas those that experience lower resource failure risk will settle for more simple toolkits. In support of her revised hypothesis, Torrence highlighted the correlation that she had previously identified between toolkit structure and latitude, as well as the correlation that Oswalt had found between toolkit structure and degree of reliance on mobile resources. She argued that the former correlation supports the risk-buffering hypothesis because distance from the equator is a proxy for overall resource abundance, which in turn is a proxy for the scale of risk. The correlation between toolkit structure and degree of reliance on mobile resources supports the risk-buffering hypothesis, Torrence argued, because a prey's mobility affects the probability of a hunter-gatherer capturing it: the higher the mobility, the larger the risk of failure.

Mobility and Toolkit Variation

The hypothesis that residential mobility influences hunter-gatherer toolkit structure was proposed by Shott (1986). Such a relationship exists, he argued, because

carrying costs constrain the number of the tools a population can employ regularly. Thus, according to Shott, populations that move frequently and/or long distances every year will have less diverse toolkits than those that move less frequently and/or shorter distances. The corollary of this is that the tools employed by highly mobile populations will be less specialised than those used by less mobile populations since they will be applied to a broader range of tasks. Shott carried out two sets of analyses to test the mobility hypothesis. The first focused on residential mobility. These analyses employed data for 14 historically documented hunter-gatherer populations. Shott conducted parametric and non-parametric analyses in which number of subsistants and average number of technounits per subsistant were correlated with several measures of mobility, including number of residential moves per year, distance traveled annually during residential moves in kilometers, average length of each residential move in kilometers, and total area occupied in square kilometers.

In the second set of analyses, which were based on smaller samples than the first set of analyses, Shott examined the relationships between the technological variables and two measures of logistic mobility: the number of days spent in the main winter camp, and intensity of land use. In addition to examining the correlations between the technological variables and measures of mobility, Shott analyzed the strength of the statistical association between the technological variables and effective temperature and net primary productivity on the grounds that Kelly (1983) had argued that these variables play a role in structuring hunter-gatherer mobility strategies.

The results of Shott's first set of analyses were mixed. Toolkit diversity and mobility frequency were found to be significantly and negatively correlated, suggesting that, as predicted, populations that move frequently employ a smaller number of subsistants than groups that are more sedentary. However, the rest of the residential mobility-focused analyses did not support the mobility hypothesis. Toolkit diversity was not significantly correlated with total distance covered per year; toolkit complexity was not significantly correlated with either frequency of residential moves per year or the average distance covered during those moves; and neither toolkit diversity nor toolkit complexity was significantly correlated with territory size.

The results of the second set of analyses were also mixed. Shott found that there was a significant positive correlation between toolkit diversity and number of days at the winter camp, which supports the mobility hypothesis. But toolkit diversity was not significantly correlated with intensity of land use, and toolkit complexity was not significantly correlated with either number of days at the winter camp or intensity of land use. Lastly, Shott found that the relationships between the technological variables and the two environmental parameters, effective temperature and net primary productivity, were not significant.

Population and Toolkit Variation

The population size hypothesis derives from cultural evolutionary modeling work carried out recently by Shennan (2000). Shennan employed two models, both of which were adapted from a population genetics model developed by Peck *et al.*, (1997) to assess the relative benefits of sexual and asexual reproduction. In Peck *et al.*'s model, mutations

can be either beneficial or deleterious; there is a correlation between an allele's fitness prior to mutation and its post-mutation fitness; and many mutations produce only very small changes in fitness. To create his first model, Shennan altered Peck *et al.*'s model so that transmission was only possible from one "cultural parent" to one "cultural offspring." To produce his second model, Shennan modified the Peck *et al.*, model so that it allowed transmission between individuals belonging to different generations where the older individual is not the biological parent of the younger individual. In simulation trials, Shennan found that there was a marked increase in the mean fitness of the population as effective population size increased. For example, in the trials of the first model there was a 10,000-fold increase in the mean fitness value of the population as effective population size increased from five to 50. Similarly, in a trial of the second model in which cultural traits were adopted from non-biological parents five percent of the time, the population's mean fitness value increased 1,000-fold as the effective population size increased from five to 25, and then increased by around five times as effective population size increased from 25 to 75.

Shennan concluded from these results that larger populations have a major advantage over smaller ones when it comes to cultural innovation due to the decreasing role of sampling effects as populations get larger. When effective population size is large there is a far greater probability of fitness-enhancing innovations being maintained and deleterious ones being deleted than when effective population size is small. One corollary of these findings is that, because each technonit represents an innovation, small populations can be

expected to have less complex toolkits than large ones. Thus, there should be a significant positive correlation between population size on the one hand, and measures of toolkit diversity and complexity on the other.

MATERIALS AND METHODS

The populations in our sample are the same as those examined by Oswalt (1976) and Torrence (1983, 1989), namely the Angmakaslik, Caribou Inuit, Chenchu, Copper Inuit, Ingalik, Ingulik Inuit, Great Andamanese, Groote-eyland, Klamath, Nabesna, Nharo, Northern Arenda, Owens Valley Paiute, Surprise Valley Paiute, Tanaina, Tareumiut Inuit, Tasmanians, Tiwi, Tlingit, and the Twana. Alternative names for these populations, as well as their geographic locations, are given in Table 2. The variables included the number of subsistants used by the groups (STS), the number of technonits in the groups' toolkits (TTS), and the average number of technonits per subsistant (AVE). The other variables were effective temperature (ET), net above-ground productivity (NAGP), the contribution of terrestrial and aquatic animals to the groups' diets (TAA), the contribution of land animals to the groups' diets (LAN), the contribution of aquatic animals to the groups' diets (AQU), number of residential moves per year (NMV), the distance traveled annually during residential moves (DMV), and population size (POP). ET and NAGP were included as measures of the risk faced by the populations following Osborn (1999). The magnitude of ET is informative regarding the length of the growing season in an area, while the NAGP of an area reflects the increase in plant biomass it experiences during the growing season (Binford 2001). We did not use Torrence's (1983, 1989, 2001)

avored measure of risk—latitude—for two reasons. First, as Osborn (1999) has noted, the fluctuations in climate that have taken place during the course of human evolution mean that latitude is unlikely to be a useful variable for assessing past human behavior. Second, latitude may be strongly correlated with measures of toolkit structure, but it is clearly unlikely to be directly causally related to them. Admittedly, ET and NPP are also unlikely to have a direct impact on toolkit diversity and complexity, but they seem likely to be closer to the environmental factors to which humans are actually responding than is latitude.

Values for the measures of toolkit structure (STS, TTS, and AVE) were obtained from Oswalt (1976). The values for the other variables (ET, NAGP, TAA, LAN, AQU, POP, NMV, and DMV) were either taken directly from Binford (2001) or calculated from data presented therein. Both Oswalt (1976) and Torrence (1983, 2000) treat the Tasmanians as a single population, but Binford (2001) separates the Tasmanians into an eastern population and a western population. Thus, where data for the Tasmanians were taken from Binford (2001), we employed the averages of the values for the eastern and western populations. Where we obtained data from Binford (2001) for the Great Andamanese, we employed the values he provides for the North Island Andamanese. This is not ideal because Oswalt's (1976) data appear to relate primarily to the non-Jarwa South Island Andamanese. However, Radcliffe-Brown (1933) maintains that the non-Jarwa South Island Andamanese and the inhabitants of the North Island belong to a single cultural group, which he terms the Great Andaman Division. Hence, it was deemed reasonable to use Binford's values for the

North Island Andamanese. The dataset is presented in Appendix A.

We restricted our sample to the populations examined by Oswalt (1976) and Torrence (1983, 1989, 2000) because we were unable to resolve certain issues with respect to the other published datasets (Osborn 1999; Shott 1986; Vierra, 1995). Two aspects of Shott's dataset are problematic. First, the toolkit structure values he provides for the Northern Arenda, Klamath, Twana, and Surprise Valley Paiute differ from the values given in Oswalt (1976), which Shott cites as the main source of his toolkit data. According to Shott (1986: 21), the Northern Arenda employ eight instruments and weapons that have an average technounit count of 2.6. Oswalt (1999: 236–237) agrees with Shott regarding the number of instruments and weapons used by the Northern Arenda, but his average technounit count for the Northern Arenda's instruments and weapons is 3.5. As with the Northern Arenda, Oswalt's and Shott's values for the total number of instruments and weapons employed by the Klamath and the Twana agree, but the values they give for the average number of technounits per tool are different. The Klamath's instruments and weapons, according to Shott (p. 21), have an average technounit count of 3.5, while the Twana's have an average technounit count of 4.9. Oswalt's (pp. 264–269) values for these populations are lower. He suggests the Klamath's instruments and weapons have an average technounit count of 3.3, while the Twana's have an average technounit count of 4.8. With regard to the Surprise Valley Paiute, both the value for subsistence number and the value for the average number of technounits per tool provided by Shott (p. 21) differ from those given by Oswalt (pp. 234–236). Shott suggests that the

TABLE 2. Populations included in the study.

Name(s)	Notes	Location
Surprise Valley Paiute	This name is employed by Oswalt (1976), Torrence (1983, 2000), and Binford (2001). In Shott's (1986) study, this population is simply referred to as the "Paiute."	Western fringe of the Great Basin, Nevada, USA (Binford 2001; Oswalt 1976).
Northern Aranda	This name is employed by Binford (2001). We have assumed it is a synonym for "Aranda" and "Arunta," which are used by Oswalt (1976). "Aranda" is also used by Torrence (1983, 2000) and Shott (1986).	MacDonnell Range, Northern Territory, Australia (Binford 2001; Oswalt 1976).
Nharo	This name is employed by Binford (2001). We have assumed it is a synonym for "Naron Bushmen," which is used by Oswalt (1976) and Torrence (1983, 2000).	Kalahari Desert, southern Africa (Oswalt 1976). The state affiliation of the Nharo is unclear. Torrence (2000) places them in Namibia, but Binford suggests that they live in Botswana (Binford 2001).
Owens Valley Paiute	This name is employed by Oswalt (1976), Torrence (1983, 2000), and Binford (2001).	Western fringe of the Great Basin, California, USA (Binford 2001; Oswalt 1976).
Tiwi	This name is employed by Oswalt (1976), Torrence (1983, 2000), and Binford (2001).	Historically, the Tiwi occupied Bathurst Island and Melville Island, which are around 48 kilometers north of the mainland Australian town of Darwin (Oswalt 1976).
Groote-eylandt	This name is employed by Binford (2001). We have assumed it is a synonym for "Ingura," which is used by Oswalt (1976) and Torrence (1983, 2000).	Historically, the Groote-eylandt occupied a group of islands near the western coast of the Gulf of Carpentaria in northern Australia (Oswalt 1976). The islands include Groote Eylandt after which the population is named (Oswalt 1976).
Chenchu	This name is employed by Oswalt (1976), Torrence (1983, 2000), and Binford (2001).	Amrabad Plateau, Hyderabad, east-central India (Oswalt 1976).
Great Andamanese	We use this name in place of Oswalt's (1976) "Adamanese," which is also employed by Torrence (1983, 2000). We do so because Oswalt (1976) indicates that his toolkit structure values for the Andamanese population in his sample are mainly based on the people from Great Andaman Island. Where we have taken data from Binford (2001) for the Great Andamanese, we have employed the values he provides for the North Island Andamanese. This is not ideal because Oswalt's (1976) data appear to relate primarily to the non-Jarwa South Island Andamanese. However, Radcliffe-Brown (1933) maintains that the non-Jarwa South Island Andamanese and the inhabitants of the North Island belong to a single cultural group, which he terms the Great Andaman Division. Hence, it was deemed reasonable to use Binford's (2001) values for the North Island Andamanese.	Great Andaman Island lies in the Sea of Bengal, southeast of India (Oswalt 1976).

TABLE 2. Continued.

Name(s)	Notes	Location
Tasmanians	Oswalt (1976) and Torrence (1983, 2000) treat the Tasmanians as a single population, but Binford (2001) separates the Tasmanians into an eastern population and a western population. Thus, where data for the Tasmanians were taken from Binford (2001), we employed the averages of the values for the eastern and western populations.	Tasmania, Australia (Oswalt 1976).
Klamath	This name is employed by Oswalt (1976), Torrence (1983, 2000), and Binford (2001).	High plateau of southeastern Oregon, USA (Oswalt 1976).
Tlingit	This name is employed by Oswalt (1976), Torrence (1983, 2000), and Binford (2001). Oswalt's (1976) toolkit structure data refer to the most northerly Tlingit group, the Yakutat Tlingit.	Gulf coast of Alaska, USA (Oswalt 1976).
Twana	This name is employed by Oswalt (1976), Torrence (1983, 2000), and Binford (2001).	Hood Canal, western Washington (Oswalt 1976).
Caribou Inuit	This name is employed by Oswalt (1976), Torrence (1983, 2000), and Binford (2001).	Barren Grounds, west of Hudson Bay, central Canada (Oswalt 1976).
Nabesna	Oswalt (1976), Torrence (1983, 2000), and Binford (2001) all use this name. Oswalt (1976) also refers to the Nabesna as the "Upper Tanana."	East-central Alaska (Oswalt 1976).
Ingalik	This name is used by Oswalt (1976), Torrence (1983, 2000), and Binford (2001). Oswalt's (1976) toolkit structure data are based on just one of the four Ingulik groups, the Anvik-Shageluk.	Western Alaska (Oswalt 1976).
Tanaina	Oswalt (1976), Torrence (1983, 2000), and Binford (2001) all employ this name.	South-central Alaska, including the Kachemak Bay area (Oswalt 1976).
Copper Inuit	This name is used by Oswalt (1976), Torrence (1983, 2000), and Binford (2001).	Coasts of Coronation Gulf, northwestern Canada (Oswalt 1976).
Ingulik Inuit	This name is employed by Binford (2001). We have assumed it is a synonym for Oswalt's (1976) "Iglulik Eskimos" and Torrence's (1983, 2000) "Iglulik." Oswalt's (1976) toolkit data are for the Iglulik proper plus the Aivilingmiut and Tununermiut.	Northern Canada (Oswalt 1976).
Tareumiut Inuit	This name is employed by Binford (2001). We have assumed it is a synonym for Oswalt's (1976) and Torrence's (1983, 2000) "Tareumiut."	Point Barrow, Alaska (Oswalt 1976).
Angmagsalik	This name is used by Oswalt (1976), Torrence (1983, 2000), and Binford (2001).	Southeast Greenland (Oswalt 1976).

Surprise Valley Paiute employ four instruments and weapons with an average technounit count of three, whereas Oswalt indicates that they used 16 instruments and weapons with an average technounit count of 2.6.

The second problematic aspect of Shott's (1986) dataset concerns the values for toolkit structure he presents for the Siriono, !Kung, and Montagnais. Shott provides data for two of Oswalt's (1976) three toolkit structure

measures—total number of subsistants and average number of technounits per subsistant. If the values Shott presents for these measures are used to generate values for Oswalt's third measure of toolkit structure—total number of technounits, it becomes apparent that Shott's values for the Siriono, !Kung, and Montagnais are incorrect. Based on the data presented in Shott's Table 2, the toolkits of the Siriono, !Kung, and Montagnais consist of 11.4, 16.2, and 9.3 technounits, respectively. These figures are dubious because, by definition, technounits counts have to be whole numbers (Oswalt 1976). Shott's toolkit structure values for the Siriono, !Kung, and Montagnais, therefore, must be erroneous.

We decided not to employ Vierra's (1995) dataset for two reasons. First, we were unable to replicate the results of one of his key multiple regression analyses with the data provided. Second, a number of the toolkit structure values he presents differ from those presented by Oswalt (1976) in an inconsistent manner. Vierra suggested that his subsistant and technounit counts were more conservative than Oswalt's, and for some groups (e.g., the Caribou Inuit and the Nabesna) this is indeed the case. For other groups, however, the subsistant and technounit counts Vierra provides are, in fact, higher than those given by Oswalt. For example, the Tiwi employ 13 subsistants and 32 technounits according to Vierra, but 11 subsistants and 14 technounits according to Oswalt. Likewise, the Twana utilise 50 subsistants and 157 technounits according to Vierra, but 48 subsistants and 236 technounits according to Oswalt. Together, these observations led us to conclude that it would be sensible to avoid incorporat-

ing Vierra's data into our analyses for the time being.

We did not use Osborn's (1999) dataset because the toolkit structure values he presented for three populations differ from those given by Oswalt (1976) even though he cited Oswalt as the source for the data. The first is the Angmagsalik. Osborn's (p. 192) and Oswalt's (pp. 293–294) datasets concur regarding this population's instrument and weapon technounit count, but they differ over the values of the other two toolkit structure measures. Osborn suggests that the instruments and weapon part of the Angmagsalik's toolkit have a subsistant count of 26 and an average technounit count of 6.5, whereas Oswalt suggests that they employ 22 instruments and weapons with an average technounit count of 7.7. The second is the Caribou Inuit. Both Osborn (p. 192) and Oswalt (pp. 278–279) suggest that the Caribou Inuit employ 13 instruments and weapons, but they differ with regard to the number of technounits from which the instruments and weapons are constructed and also about the average number of technounits per subsistant. Osborn indicates that the Caribou Inuit's instruments and weapons consist of 51 technounits and have an average technounit count of 3.9, whereas Oswalt suggests that their instruments and weapons consist of 42 technounits and have a technounit count of 3.2. The third population that Osborn and Oswalt disagree about is the Tasmanians. Osborn (p. 192) shows the Tasmanians as having a subsistant count of 12, a techno-unit count of 12, and an average technounit count of 1.0. Oswalt (pp. 263–364) concurs with Osborn regarding the average technounit count for the instrument and weapon part of the Tasmanians

toolkit, but disagrees with him regarding its subsistant count and technounit count. According to Oswalt (p. 263), the Tasmanians used six one-technounit instruments and weapons. Once again, we felt it was prudent not to incorporate Oswalt's data in our analyses until we were able to identify the cause(s) of the discrepancies.

Two sets of analyses were carried out to investigate the relative importance of the predictor variables as influences on toolkit structure. The first set incorporated data for all types of subsistant for which Oswalt (1976) provides data, namely instruments, weapons, and facilities. Exploratory analyses indicated that the values for most of the variables were normally distributed. However, the data for ET, NAGP, DMV, and POP were found to be significantly right skewed at the 0.05 level ($g_1 = 1.986$, $g_1 = 3.035$, $g_1 = 2.275$, and $g_1 = 5.129$, respectively). To counteract this, the values for the three variables were converted into natural logarithms (LET, LNAGP, LDMV, LPOP); the transformed data were normally distributed. Thereafter, stepwise linear multiple regression analysis was used to regress each of the three toolkit structure measures (STS, TTS and AVE) against the predictor variables (LET, LNAGP, TAA, LAN, AQU, NMV, LDMV, LPOP). In the second set of analyses, the measures of toolkit structure were computed on the basis of just instruments and weapons. This set of analyses was performed in order to test Shott's (1986) mobility hypothesis more fairly, since he disregarded facilities in his analyses on the grounds that they are not often carried between residence sites, and therefore are unlikely to be affected by residential mobility in the same way as portable tools. First, the values for the total number of technounits were trans-

formed into natural logarithms since they were found to be significantly right skewed ($g_1 = 2.430$). Next, we carried out three stepwise linear multiple regression analyses in which each toolkit structure measure was regressed against the seven predictor variables. All the regression analyses were carried out in SPSS 11. In each analysis, the probability of F to enter was set at less than or equal to 0.050, and the probability of F to remove was set at greater than or equal to 0.1.

RESULTS

The results of the two sets of analyses are presented in Tables 3 and 4. The stepwise regression analysis in which the all-tool STS values were regressed against the values for LET, LNAGP, TAA, LAN, AQU, NMV, LDMV, and LPOP indicated that only LET had a significant impact on STS ($p \leq 0.001$). The beta weight for LET in the STS analysis was -0.676 . The beta weights for the other ecological variables were all considerably lower. They ranged from -0.220 (NMV) to as low as -0.004 (LAN). The results of the other analyses were similar. LET was the only predictor variable that significantly influenced the all-tool TTS ($p \leq 0.001$). The beta weight for LET in this analysis was -0.704 . The next highest beta weight was -0.317 (NMV), and the lowest was 0.040 (LPOP). In the analysis in which the all-tool AVE was regressed against LET, LNAGP, TAA, LAN, AQU, NMV, LDMV and LPOP, the beta weight for LET was -0.603 ($p \leq 0.005$). The beta weights for the other variables ranged from -0.332 (LDMV) down to 0.033 (LPOP). Thus, the results of the three all-tool analyses were clear-cut. Of the various ecological variables considered, only LET has a significant impact on toolkit structure when all tool types were considered. The results of the second set of analyses agreed with

TABLE 3. Beta weights obtained in stepwise linear multiple regression analyses in which values for the toolkit structure measures were based on all tools. STS=total number of subsistants. TTS=total number of technounits. AVE=average number of technounits per subsistant. LET=natural logarithm of effective temperature. LNAGP=natural logarithm of net above ground productivity. NMV=number of residential moves per year. LDMV=natural logarithm of distance traveled annually during residential moves. TAA=percentage contribution of terrestrial and aquatic animals to diet. LAN=percentage contribution of terrestrial animals to diet. AQU=percentage contribution of aquatic animals to diet. LPOP=natural logarithm of population size. * = p value significant at the 0.05 level. ** = p value significant at the 0.01 level.

	LET	LNAGP	NMV	LDMV	TAA	LAN	AQU	LPOP
STS	-0.676 p=0.001**	0.189	-0.220	-0.103	-0.031	-0.004	-0.16	-0.022
TTS	-0.704 p=0.001**	0.257	-0.317	-0.248	0.198	-0.051	0.170	0.040
AVE	-0.603 p=0.005**	0.049	-0.305	-0.332	0.169	-0.094	0.187	0.033

TABLE 4. Beta weights obtained in stepwise linear multiple regression analyses in which values for the toolkit structure measures were based on portable tools only. LTTS= natural logarithm of total number of technounits. * = p value significant at the 0.05 level. ** = p value significant at the 0.01 level. Other abbreviations as per Table 3 caption.

	LET	LNAGP	NMV	LDMV	TAA	LAN	AQU	LPOP
STS	-0.621 p=0.004**	0.119	-0.355	-0.337	-0.081	-0.202	0.118	-0.013
LTTS	0.596 p=0.006**	-0.315	-0.237	-0.247	-0.174	-0.174	0.036	-0.067
AVE	-0.181 p=0.004**	-0.609	-0.226	-0.303	0.181	-0.251	0.277	-0.138

those of the first set regarding STS and TTS, but differed with respect to AVE. LET was the only predictor variable that significantly influenced the portable-tool STS (beta = -0.621, $p \leq 0.004$) and TTS (beta = -0.596, $p \leq 0.006$). The only predictor variable that significantly influenced portable-tool AVE was LNAGP (beta = -0.609, $p \leq 0.004$).

DISCUSSION

Overall, the results of our analyses are in line with Torrence's (1989, 2000) suggestion that risk of resource failure is the

primary influence on hunter-gatherer decision-making about the number and complexity of subsistence tools to manufacture and employ. The only predictor variables that significantly influenced the toolkit structure measures were LET and LNAGP, both of which were included in the analyses as proxies for risk. The analyses do not support Oswalt's (1976) and Osborn's (1999) arguments regarding the impact of resource type on hunter-gatherer toolkits. Neither the populations' degree of reliance on mobile resources nor their degree of reliance

on aquatic resources was found to have a significant impact on the diversity or complexity of their toolkits. The analyses also do not support Shott's (1986) contention that mobility influences toolkit structure. None of the measures of toolkit structure were significantly influenced by number of residential moves per year or by distance traveled annually during residential moves. Lastly, our analyses do not support the hypothesis that population size affects hunter-gatherer toolkit structure. Population size was not significantly correlated with any of the measures of toolkit diversity and complexity.

While our analyses offer strong support for Torrence's (1989, 2000) risk-buffering hypothesis, we caution against accepting the hypothesis too enthusiastically at this stage. Too many issues remain unresolved. One of these is the appropriateness of effective temperature and net above-ground productivity as proxies for risk of resource failure. As noted earlier, we selected these variables because they are probably closer to the factors that directly affect hunter-gatherer technological decision-making than the proxy variable used by Torrence—latitude. However, both effective temperature and net above-ground productivity relate to primary biomass (i.e., plants and other organisms that obtain their energy directly from solar radiation through photosynthesis), and it has been argued that the availability of primary biomass is less important to hunter-gatherers than the availability of secondary biomass (i.e., herbivorous animals) (Keeley 1988). It is not clear that this suggestion holds for all hunter-gatherer populations, since a number of them are heavily dependent on plant resources. Nevertheless, a sensible next step would be to determine the impact

of secondary productivity on hunter-gatherer toolkit diversity and complexity, and then compare it to the impact of effective temperature and net above-ground productivity.

A second issue that makes us hesitant regarding our analyses' support for the risk-buffering hypothesis is the size and composition of the sample of hunter-gatherer populations. By any standard, 20 populations is a small sample. A modest sample need not be problematic if it is representative, but the sample used in the present study is far from representative. As shown in Table 5, more than half of the populations are from the northern part of the western hemisphere. Eight of them live in Canada or Alaska, two others live in the northwestern United States, and a

TABLE 5. Distribution of populations in sample by landmass.

Landmass	Population
Africa	Nharo
Andaman Islands	Great Andamanese
Australia	Northern Arenda Tiwi Tasmanians Groote-eylandt
India	Chenchu
Greenland	Angmagsalik
North America	Surprise Valley Paiute Owens Valley Paiute Klamath Tlingit Twana Caribou Inuit Nabesna Ingalik Copper Inuit Ingulik Inuit Tanaina Tareumiut

further population lives in southwestern Greenland. Hunter-gatherer populations from other parts of the world are poorly represented. The sample contains only one hunter-gatherer population from Africa and one from India. None of the ethnographically-documented South American hunter-gatherer populations are included in the sample. Thus, the dataset contains a strong bias towards high latitude environments. The dataset contains an equally strong bias towards coastal environments. Very few of the populations in the sample inhabit the interior of a continent. Accordingly, it is not clear that the results of our analyses can be legitimately extrapolated to the global scale.

Non-Conforming Populations

The notion that our analyses' support for the risk-buffering hypothesis might be sample specific is reinforced by consideration of some hunter-gatherer populations that were not included in the sample and that do not conform to the prediction that toolkit diversity and complexity should be positively correlated with risk of resource failure. The Yahgan of Tierra del Fuego are one such population. Tierra del Fuego is "a rugged, wind swept, cold, and mountainous region," with a mean annual temperature range of 0 to 10°C, and yearly rainfall of between 2,030 mm in the north of the area and 3,050 mm in the south (Steward and Faron 1959: 397). Tierra del Fuego is also "comparatively poor in fish, game, and wild food plants" (Steward and Faron 1959: 398). Thus, the Yahgan lived in an inhospitable environment, and it is reasonable to suppose that they continually faced considerable risk of resource failure. Yet according to Oswalt (1973: 98), in the early part of the 20th century, the

Yaghan employed a toolkit comprising only 69 technounits. Thus, contrary to the risk-buffering hypothesis, the Yaghan operated a relatively simple toolkit in a high-risk environment.

The Calusa of southern Florida are a second hunter-gatherer population that does not conform to the risk-buffering hypothesis. Southern Florida, like other tropical coastal zones, is an area of high net primary productivity. The climate of mild winters, hot summers, a yearly frost-free season in excess of 240 days, and an annual rainfall around 1,143 millimeters, results in abundant plant and animal life (Martin *et al.* 1947; Widmer 1988). The food resources available to humans in such areas are nutritionally complete, and Widmer (1988: 278) suggests that they have "protein to calorie ratios much higher than are required by humans." Moreover, many sources of protein in tropical coastal zones are easily captured because of their relatively fixed location (Widmer 1988). Although southern Florida has a reasonably long dry season in the winter and spring, Widmer (1988) argues that the fact that the periods of maximum availability of the major fish species are sequential would have allowed continuous year-round exploitation of fish resources. In keeping with this, fish remains constitute the majority of the vertebrate faunal assemblages at most Calusa archaeological sites, and historical sources repeatedly emphasise the abundance of fish in the region. Murdock (1969: 141) suggests that gathered wild plant resources accounted for only 20% of the Calusa's diet, and there is no evidence for agricultural production at any of the Calusa sites (Marquardt 1988; Widmer 1988). Thus, the Calusa's environment was such that it seems unlikely that they would have faced substantial resource

failure risk. On the contrary, they seem likely to have ready access to food all year round.

The Calusa are known only from ethnohistoric accounts and the archaeological record, which means that subsistence and technounit counts are not readily available for them. Nevertheless, there can be little doubt that they did not conform to the prediction regarding toolkit structure and risk. Based on the risk-buffering hypothesis, the Calusa would be expected to have employed a relatively simple toolkit. However, it is clear from the work of Marquardt (1984, 1986, 1988) and particularly Widmer (1988: 250–255) that the Calusa employed numerous complex subsistence tools. Widmer (1988: 250), for example, notes that a number of types of harpoon and spear point have been recovered from the site of Key Marco, including a single barbed bone harpoon point, a stingray spine spear point, and a long, barbless, spikelike alligator bone spear point. The attributes of these various implements, Widmer (1988) argues, suggest functional differences, and thus it seems likely that they would be deemed different subsistants using Oswalt's (1976) tool classification method. Multipart fishhooks have also been recovered from a number of sites in the Calusa region, as have the remains of grouper (*Epinephelus* sp., *Mycteroperca* sp.) and snapper (*Lutjanus* sp.), which can only have been caught with hook and line as they are offshore species that are solitary in habit (Widmer 1988). Other line-fishing tools have been found at the site of Key Marcos, including plug-shaped floats of gumbo-limbo wood, sinkers made of short, thick columellae of turbinella shells, flat, wooden reels or spools, shuttles or skeinholders of hardwood, and a double barbed point

with cord binding and a concave rounded plate (Widmer 1988). Again, it seems likely that Oswalt's (1976) method would recognise each of these artifacts as distinct subsistants.

The impression that the Calusa employed a complex toolkit is reinforced by evidence for net and trap fishing. On Mario Island, for instance, Widmer (1988: 253) reports that "bountiful netting" was recovered. Two main types of net seem to have been employed by the Calusa: a fine-meshed, square dip net, and a coarse-meshed, comparatively large and long gill-net. Both types of net would appear to have had shell sinkers attached to them, as well as floats and float pegs. The floats were made of gourd, long wooden sticks, or square-ended wooden blocks; the float pegs were made from gumbo-limbo wood. The mesh sizes of the nets ranged from 3 to 6 cm, indicating, according to Widmer (1988), that specific species were sought and/or different types of fishing ground were exploited by the Calusa. As yet, the remains of fish traps have not been recovered archaeologically and there is little ethnographic evidence of their use (Widmer 1988), but fish weirs are documented historically in Tampa Bay, and the occurrence of toadfish (*Opsanus beta*) on Calusa sites implies the use of traps (Widmer 1988). Overall, there would seem to be good reason to believe that, contrary to the risk-buffering hypothesis, the Calusa manufactured and used a complex toolkit in a relatively low risk environment.

Comparison of the toolkits and environments of San hunter-gatherers casts further doubt on the credibility of the risk-buffering hypothesis. In the late 1800s, the floodplain of the Botletli River in the northern Kalahari was occupied by three San hunter-gatherer

populations—the Beteti (Deti), Tshaiti, and //Kanikhoe (Tshumakhoe). It is clear from the work of Cashdan (1985, 1986, 1987) that these populations occupied a considerably richer habitat than the better-known desert San populations, such as the !Kung and Nharo. She reports that the Botletli River provides a strip of fertile land in an otherwise dry and barren country, and describes how during the 19th century the river was rich in fish and how its floodplain teemed with wildlife. Based on the risk-buffering hypothesis, the richness of the Botletli River San populations' habitat would lead us to expect that they would have less diverse and less complex toolkits than the desert San. However, this is not what we find. According to Cashdan, the Beteti, Tshaiti, and //Kanikhoe all utilized the same basic toolkit as the desert San populations, but also made use of a wide range of fishing-related tools, including stone fishing weirs, reed fishing weirs, fish traps, fish baskets, fish spears, poison, and woven nets. Thus, the Botletli River San employed more diverse and complex toolkits than the desert San even though they experienced a lower risk of resource failure. Once again, the relationship between risk and toolkit structure predicted by the risk-buffering hypothesis does not hold.

Needless to say, the small size and biased composition of the sample used in the analyses are not reasons for rejecting the risk-buffering hypothesis. Likewise, the risk-buffering hypothesis should not be abandoned on the grounds that we can identify a few cases that apparently do not conform to its predictions. However, the sample problems and the conflicting examples strongly suggest that further work needs to be directed towards examining the

impact of risk, diet composition, mobility and other factors on the subsistence technology-related decision-making of hunter-gatherers. In particular, there would appear to be a pressing need to supplement Oswalt's (1976) dataset with toolkit diversity and complexity counts for hunter-gatherer populations living at low-latitudes and/or in mid-continental environments.

CONCLUSIONS

In this paper we have focused on the factors that affect hunter-gatherer decision-making regarding the diversity and complexity of their food-getting tools. We have used stepwise multiple regression analysis and a 20-population dataset to evaluate the relative importance of four factors that there is reason to think may influence the structure of hunter-gatherer toolkits—the nature of the resources exploited for food, risk of resource failure, residential mobility, and population size. Our analyses suggest that risk of resource failure has a significant impact on toolkit diversity and complexity. In contrast, our analyses do not support the hypothesis that the characteristics of the resources exploited for food influence hunter-gatherer toolkit structure. They also do not support the suggestion that residential mobility affects hunter-gatherer toolkit diversity and complexity, or the notion that population size has an impact on hunter-gatherer toolkit structure. While our analyses strongly support the suggestion that resource failure risk is the primary influence on hunter-gatherer toolkit diversity and complexity, we argue that it would be premature to discount the other factors at this stage, because of problems with the size and representativeness of the dataset. Accordingly, further work needs to be directed towards examining the

impact of risk, diet composition, mobility, population size, and other factors on the subsistence technology-related decision-making of hunter-gatherers.

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APPENDIX A. Data used in analyses. NHG=name of hunter/gatherer population. All STS=total number of subsistants among all tools. All TTS=total number of technounits among all tools. All AVE=average number of technounits per subsistant among all tools. Portable STS=total number of subsistants among portable tools. Portable LTTS=log of total number of technounits among portable tools. Portable AVE=average number of technounits per subsistant among portable tools. NMV=number of residential moves per year. DMV=Distance traveled annually during residential moves. TAA=percentage contribution of terrestrial and aquatic animals to diet. AQU=percentage contribution of aquatic animals to diet.

NHG	All STS	All TTS	All AVE	Portable STS	Portable LTTS	Portable AVE	NMV	LDMV	TAA	AQU	LET	LNAGP
Surprise Valley Paiute	39	97	2.49	16	3.74	2.6	9	5.35	50	20	2.54	5.61
Northern Aranda	16	42	2.63	8	3.33	3.5	14	5.65	45	0	2.77	5.52
Nharo	12	40	3.33	7	3.18	3.4	2	3.43	33	0	2.78	6.06
Owens Valley Paiute	28	107	3.82	13	3.97	4.1	2	2.83	35	5	2.62	4.24
Tiwi	11	14	1.27	9	2.49	1.3	10	4.32	60	35	3.01	7.73
Groote-eylandt	13	32	2.46	9	3.09	2.4	8	4.09	70	60	3.00	7.57
Chenchu	20	55	2.75	14	3.66	2.8	4	2.64	15	5	3.02	7.55
Great Andamanese	11	51	4.64	8	3.66	4.9	12	4.33	40	5	3.15	8.00
Tasmanians	11	15	1.36	6	1.79	1	9.5	4.75	80	50	2.54	6.82
Klamath	43	151	3.51	16	3.97	3.3	6	4.43	70	50	2.48	5.66
Tlingit	28	121	4.32	12	3.47	2.7	3	3.40	99	84	2.42	6.63
Twana	48	237	4.94	16	4.34	4.8	4	4.17	90	70	2.55	6.55
Caribou Inuit	34	118	3.47	13	3.74	3.2	16	6.09	100	45	2.31	4.50
Nabesna	25	105	4.20	9	3.61	4.1	14	5.77	9	57	2.37	5.32
Ingalik	55	296	5.38	19	4.36	4.1	4.00	4.16	98	55	2.38	6.03
Tanaina	40	224	5.60	23	4.56	4.2	2.00	3.58	97	46	2.37	6.08
Copper Inuit	27	122	4.52	12	4.23	5.8	14.00	6.10	100	75	2.28	3.75
Ingulik Inuit	42	225	5.36	23	5.01	6.5	12.00	5.95	100	85	2.25	3.68
Tareumiut Inuit	35	205	5.86	19	4.91	7.2	3.00	4.09	100	75	2.18	3.79
Angmagsalik	33	202	6.12	22	5.13	7.7	2.00	2.57	99.99	89.99	2.20	5.23